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ANSWERS

PEARSON BACCALAUREATE

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Biology

2nd Edition

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Answers

Chapter 1

Answers are not provided for questions that require individual research or practice.

Exercises

- 1 As the surface area to volume ratio decreases, there is relatively less membrane surface to allow the exchange of wastes between the inside and outside of the cell. The surface area increases much more slowly than the volume when the diameter of a cell increases. Thus, the relative amount of membrane available for exchange is less. If a cell grows too large, the result is cell death because of waste accumulation.
- 2 Paramecia are heterotrophs and must gain their nutrition by ingestion of nutrients from their surroundings. *Chlorella* are autotrophs and are able to capture sunlight to carry out photosynthesis, thus they can make their own nutrition.
- 3 These cells have very specific roles in the organism. Nerve cells conduct impulses, and to do this they require adaptations that allow depolarization and repolarization or rapid electrical changes within them. Muscle cells produce movement; they possess certain proteins and specific arrangements of these proteins to bring about movement. The result is that nerve and muscle cells carry out their functions without expending valuable time and energy in a reproductive stage.
- 4 Even though stem cells are capable of great variation in what they differentiate into, they still have nuclear DNA as their controlling factor. The DNA of one animal is potentially quite different from the DNA of another.
- 5 The DNA is more vulnerable to the life functions of the cell. These cell functions require enzymes and raw materials, and produce products that may potentially damage the DNA. This creates a greater chance of interactions and mutations or harmful changes.
- 6 Pili are plasma membrane extensions that allow bacterial cells to join so that exchange of DNA between cells can occur, thus bringing about sexual reproduction.
- 7 The area just outside the cell wall of bacteria contains proteins, long-chain polysaccharides, and lipids that allow the bacteria to stick to the tooth surface.
- 8 Muscle cells have a large number of mitochondria because their function is to allow movement. Mitochondria produce ATP, and ATP is essential to enable special proteins to slide alongside one another and create movement. If ATP is not present, movement is not possible.
- 9 Mitochondria and chloroplasts, because they have their own DNA; have an additional outer membrane, indicating a need for greater protection within a potentially hostile environment; have ribosomes similar to prokaryotic ribosomes; divide by simple fission.
- 10 Chloroplasts produce simple carbohydrates. These carbohydrates are sources of chemical energy when their chemical bonds are broken. The energy can be used to produce ATP, which is necessary for cellular activities. Mitochondria enable the breakdown of the chemical bonds to release the energy.
- 11 The presence of a scale bar means that the actual size of the object in the micrograph can be worked out.
- 12 The hydrophilic portions of the phospholipids align themselves to the locations where the polar molecules of water exist (outside and inside the plasma membrane). The hydrophobic portions of the phospholipids align themselves to the inside of the membrane where there is no contact with the polar water molecules.
- 13 There is no cholesterol in the membranes of plants and plant products. Animal products have plasma membranes, which contain cholesterol.

- 14** Amphipathic phospholipids have both hydrophilic and hydrophobic properties.
- 15** Molecules of carbohydrates producing glycoproteins.
- 16** In passive transport, the driving force is the concentration differences of a particular substance type. When concentrations are high, molecular collisions occur more frequently resulting in movement towards areas of lower concentration. This movement outwards will continue until collisions are occurring equally throughout the area, by which time equilibrium is said to be established. In active transport, there is no final equilibrium. Active transport is movement against a concentration gradient with the expenditure of energy.
- 17** Non-polar amino acids are present because the inner region of the membrane is made of the non-polar regions of the membrane phospholipids.
- 18** Both exocytosis and endocytosis require expenditure of energy in the form of ATP.
- 19** Bacteria in the air were able to enter the flask and grow in the nutrient broth.
- 20** Diverse explanations are possible here. There is no clear evidence of how the first nucleus developed. It may have developed as mitosis-like divisions resulted in compact genomes. It may have occurred with plasma membranes breaking into the interior, resulting in the nuclear membrane. This is presently being hypothesized and researched.
- 21** Emergent properties indicate greater outcomes for the whole than would be expected when simply adding up the individual abilities of each part. When *Hatena* and the alga combine, their abilities are pooled together, allowing greater abilities than anticipated.
- 22** The cells on Earth today are here because of changes to the first cells that appeared on Earth. Endosymbiosis and other changes resulted in the more complex cells of today compared with the very simple first cells.
- 23** The chromosomes would be abnormally distributed, resulting in cells with improper DNA to govern cellular processes. The result would be abnormal cells that probably would die very early.
- 24** Since the chromatids are yet to separate in metaphase, there would be 48 chromatids present.
- 25** Cytokinesis occurs at the conclusion of the M phase (mitosis) and just before interphase begins (G_1).
- 26** Animal cell cytokinesis involves pinching in of the plasma membrane from the outside to separate the two sets of chromosomes. Plant cell cytokinesis involves the formation of a cell plate that develops between the cell wall and plasma membrane to separate the two sets of chromosomes; the cell plate forms inside the cell and builds toward the exterior cell wall.
- 27** The mitotic index can be used to predict the response of cancer cells to chemotherapy. The higher the index, the faster the rate of mitosis.

Practice questions

- 1 (a) (i)** interphase because no (individual) chromosomes are visible/
genetic material visible as chromatin/
chromosomes/DNA has not
condensed/nuclear envelope/
nucleolus/nucleus is visible (1)
- (ii)** DNA synthesis/replication/OWTTE;
(cell) growth/increase in the number of
organelles/specific organelle mentioned;
transcription/synthesis of RNA (2 max)
- Mark only the first process on each line
if more than two processes are listed.
Do not accept error carried forward if
mitosis is the answer in (i).*
- (b)** retain the capacity to divide; they are
undifferentiated/unspecialized;

have the ability to differentiate (along different pathways)/are multipotent/pluripotent/totipotent (2 max)

Mark only the first process on each line if more than two processes are listed.

- (c) named source of stem cells e.g. bone marrow/cord blood/inner cell mass of embryo/embryonic stem cells; name of condition that is treated using the stem cells e.g. leukaemia/heart disease/diabetes/other possibility; one precise detail of how the stem cells replace/replenish (differentiated) cells that are the cause of the condition (3 max)

Example:

Source: stem cells obtained from bone marrow;

Condition: leukaemia;

Detail: patient's bone marrow cells (are killed and) replaced with the stem cells

(Total 8 marks)

- 2 A (Total 1 mark)
3 C (Total 1 mark)
4 D (Total 1 mark)

- 5 (a) (i) 50 000 (*Accept answers in the range of 50 000 to 53 000*) (1)
(ii) 0.1 μm (*units required*)
Allow answers in the range of 0.09 μm to 0.12 μm (1)

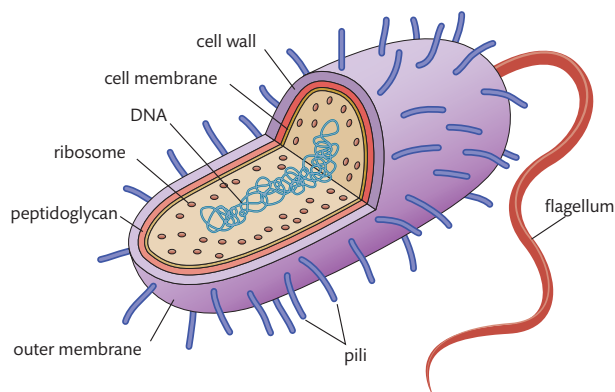
- (b) Award [1] for any two of the following.
growth/production of (extra) body cells; (*do not accept cell growth*)
first stage of spermatoo/gametogenesis/
forming oogonia/spermatogonia;
embryo development;
wound healing/(tissue) repair/hair growth/
replacement of skin cells; (*do not accept repairing cells*)
clonal selection/division of lymphocytes (for antibody production)
Do not accept asexual reproduction. Do not award a mark if one of the first two answers is incorrect. (1 max)

- (c) stem cells are undifferentiated cells;
embryo cells are stem cells; stem cells can differentiate in many/all ways/are pluripotent/totipotent; differentiation involves expressing some genes but not others; stem cells can be used to repair/replace tissues/heal wounds (3 max)

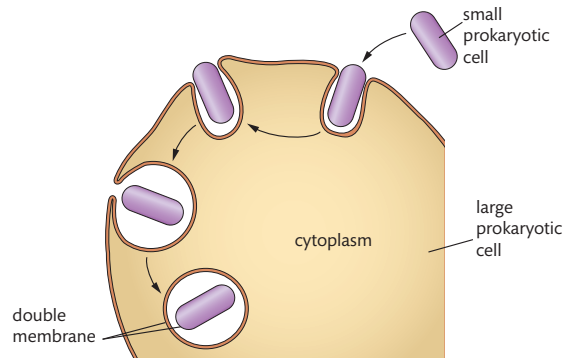
(Total 6 marks)

Challenge yourself

- 'Response' is the function of life demonstrated. This response allows the paramecia to move to a location where it is most likely to survive.
- Nutrition.
- Excretion.
- A contractile vacuole expands as water concentrations increase in a microorganism. Once fully expanded, the contractile vacuole then contracts, pushing excess fluids through the attached radiating canals. Non-digestible food that enters paramecia exit the cell via the anal pore.
- Things to note on the drawing: The plasma membrane should be adjacent to but separate from the cell wall. The ribosomes should be dot-like structures within the cytoplasm because of their small size. In the case of ribosomes there should be many, many dots, reflecting the large numbers of ribosomes that occur in most bacterial cells.



- 6 Diffusion.
- 7 There is no expenditure of energy on the part of the cell.
- 8 As solutes move from the blood into the dialysate, the concentration gradient of the solutes between the blood and the dialysate decreases, which slows the cleansing process of the blood.
- 9 Characteristics that affect the rate of movement include the size of solute particles, the charge of solute particles and the concentrations of solute particles on both sides of the membrane.
- 10 Osmosis.
- 11 Factors affecting the time needed include the concentration of solutes and wastes in the blood, the percentage water composition of the blood (due to adequate or inadequate hydration), and the actual types of solutes and wastes present in the blood.
- 12 The cells will gain mass. This is because when cells are placed in a hypotonic solution, there are fewer osmotically active particles outside the cells than inside. That means there is a higher concentration of water molecules outside the cells than inside. Because of osmosis, water will then move into the cells along a concentration gradient.
- 13 The salt particles are osmotically active particles in the soil. Because of the larger number of particles in the soil, there is a higher concentration of water in the cells than in the soil. Water leaves the roots, resulting in death of the plants. Plants will not grow in this area until the salt particles are washed away.
- 14 The drawings should follow the most logical explanation: (1) the bacterial cell (potential organelle) comes into contact with the larger cell; (2) engulfing (phagocytosis) occurs; (3) a section of the larger cell's plasma membrane surrounds the engulfed bacterial cell; (4) two membranes are now present, the one provided by the receiving cell and the one already intact on the bacterium.



- 15 More than 900. However, the number should not be too high as interphase still is the longest phase of the cell cycle with cancer cells.
- 16 The cancer cells would have a shorter cell cycle time, thus illustrating their more rapid growth rate.
- 17 The cancer tissue has a higher mitotic index because they are dividing at a more rapid rate.

Labs

1.1 *Chlorella* and the functions of life

- 7 Response and nutrition should be mentioned here. Response is the movement towards light so that photosynthesis can occur. Nutrition is the process whereby the organism uses light to produce most of the nutrients it needs to survive. The *Chlorella* would eventually die in the dark once the supply of nutrients had been used up.

1.2 The use of a light microscope to investigate cells and cell structures

- | | |
|----|-------------------|
| 4a | 5000 |
| 4b | 250 μm |
| 4c | 10 mm |

1.4 Membrane transport

- 9 The point at which the line of the experimental results crosses the x-axis indicating zero per cent change should indicate the osmolarity of the

potato tissue. The actual value will vary because of variations in potatoes and procedural variations.

For the data points on the graphs to be accurate, measurements must be extremely accurate. Even slight errors in procedures and/or measurements will result in data that will not yield valid conclusions.

Answers regarding how the procedure could be altered will vary depending on the exact details of the procedure carried out by the student. Suggestions should include meaningful and not elementary explanations.

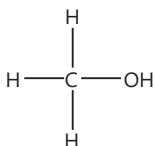
Answers

Chapter 2

Answers are not provided for questions that require individual research or practice.

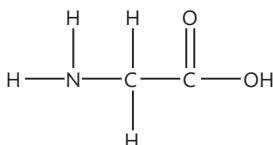
Exercises

1 (a)



Formula = CH_4O
or CH_3OH

(b)



Formula = $\text{C}_2\text{H}_5\text{O}_2\text{N}$

2 (a) Many glucose molecules.

(b) Lactose and water.

(c) One glycerol and three fatty acid molecules.

3 Metabolism is a combination of anabolism and catabolism. Anabolism often involves small 'building block' molecules being bonded together by condensation reactions into macromolecules. Catabolism often involves the hydrolysis of macromolecules into monomers.

4 Many different possible answers exist for this question. You should pick an organism that you are familiar with. Ways in which water is important could include, but are not limited to: water for cytoplasm in every cell; blood plasma; environment for all chemical reactions; distribution of nutrients within the organism; distribution of wastes within the organism; habitat for some organisms; redistribution of water often changes the shape of some cells/organisms (e.g. guard cells in plants); maintenance of stable internal temperature.

5 Answers for this question are also expected to be highly varied. Many answers will and should focus on the polarity of water molecules.

Chemical reactions are only possible in cells, blood plasma, etc., because the majority of solutes in living organisms are polar and are thus water soluble. Polarity is also directly related to cohesion and adhesion of water molecules, and is important in any answer dealing with movement of water. Maintenance of a stable internal temperature is directly related to the high specific heat of water, and also attributed to the polarity of water molecules.

6 glycerol + 3 fatty acids $\rightarrow$ triglyceride + 3 water

7 *trans* fatty acid, saturated fatty acid, unsaturated fatty acid.

8 Body mass does not account for differences in heights between individuals.

9 (a) Proline.

(b) Methionine and cysteine.

(c) Aspartic acid, glutamic acid, lysine, arginine, and histidine.

10 75 (there is always one less peptide bond than the number of amino acids).

11 160 000 combinations. Each position would have a 1 in 20 chance of being any one amino acid. Thus, $20 \times 20 \times 20 \times 20 = 160\,000$.

12 The specificity is explained by a combination of molecular shapes that must correspond and molecular charges that must align. The substrate must have a complementary/opposite shape to the active site of the enzyme. In general, if an enzyme has an internal positive charge, then the substrate will have a negative charge, although there are exceptions to this.

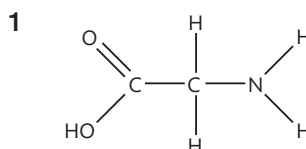
13 They are neither a reactant nor a product. In addition, they influence the rate of the reaction. The difference between a non-enzyme catalyst and an enzyme is that an enzyme is organic.

- 14 One way of answering this is to predict the hydrogen ion content of each solution relative to the other. As pH is a logarithmic scale, the solution of pH 3 has 1000 times more hydrogen ions compared with the solution of pH 6.
- 15 The phosphate groups and deoxyribose sugars within DNA molecules are constant. There is no genetic information (message) written within their presence. The only message is the order of the nucleotides as given by the order of the nitrogenous bases. It is also common to give only one side of a double-stranded molecule because it is obvious what the complementary strand is.
- 16 Compare your answer with Figure 2.32. Be certain the bases are in the correct sequence and are properly base-paired.
- 17 Hydrogen bonds.
- 18 Codons occur on mRNA and are made up of three RNA nucleotides. Triplets are three nucleotide bases of DNA that produce codons by complementary base pairing.
- 19 Transcription and translation.
- 20 Phosphate, pentose sugar, and a nitrogenous base.
- 21 Glycolysis.
- 22 In the cytoplasm.
- 23 All cells need some form of cell respiration and all have cytoplasm; only eukaryotic cells have mitochondria.
- 24 The inhaled oxygen is distributed by blood to our body cells for cell respiration, and the by-product is carbon dioxide. Carbon dioxide is carried back to our lungs and we breathe it out.
- 25 A blue object would absorb the red and green areas of the visible light spectrum and would reflect the blue wavelengths. The colour reflected is the colour that we see.
- 26 Black surfaces absorb all colours (wavelengths) and reflect none. This means more energy is

being absorbed and so black surfaces get hotter than lighter surfaces in sunlight.

- 27 If the sugar is needed for energy, it enters the process of cell respiration to generate ATP. If the plant does not need all the glucose for energy at that time, the excess is typically converted to starch (amylose).
- 28 Most plants experience a 'growing season' in which far more sugar is produced than is necessary to stay alive at that time. The excess is converted to starch and can be used in the 'non-growing' season (usually the cold months of the year).

Practice questions



carboxyl and amine groups shown as part of a molecule; alpha/central carbon atom with carboxyl and amine groups bonded to it correctly radical and hydrogen also bonded correctly to (alpha) carbon; label indicates peptide bond forms between -COOH and -NH₂ groups/label indicates peptide bond forms between groups labelled as amine and carboxyl groups

(Total 4 marks)

- 2 D (Total 1 mark)
- 3 A (Total 1 mark)
- 4 water is transparent/allows light to pass through for photosynthesis; cohesion of water molecules allow transport in plants; solvent – chemical reactions take place in water; many substances dissolve in water and can be transported; high boiling point makes liquid water available to organisms/water is liquid over a range of temperatures; water is most dense at 4°C so ice floats over water providing winter habitat; high

specific heat capacity so stable environment (internal/external); high surface tension – supports (near) surface-dwelling organisms; coolant – absorbs heat when it evaporates/ changes states

(Total 5 marks)

5 B

(Total 1 mark)

6 (a) 40°C

(1)

(b) 40°C: $3.5 \mu\text{mol m}^{-2} \text{s}^{-1}$; (units required)

Accept answers between $3.0 \mu\text{mol m}^{-2} \text{s}^{-1}$ and $4.0 \mu\text{mol m}^{-2} \text{s}^{-1}$.

50°C: $10 \mu\text{mol m}^{-2} \text{s}^{-1}$; (units required)
Accept answers between $9 \mu\text{mol m}^{-2} \text{s}^{-1}$ and $11 \mu\text{mol m}^{-2} \text{s}^{-1}$.

(2)

(c) rate of respiration is increasing

(1)

(d) (i) rate increases as the temperature increases up to a point/40°C and then decreases

(1)

(ii) at low temperatures/between 25°C and 35°C the rate of photosynthesis increases and the rate of respiration is (approximately) constant; between 35°C and 40°C both increase; as temperature continues to increase the rate of photosynthesis reaches optimum

whereas rate of respiration decreases less/stays constant/increases; at high temperatures/between 40°C and 50°C photosynthesis decreases as respiration decreases less/stays constant/increases

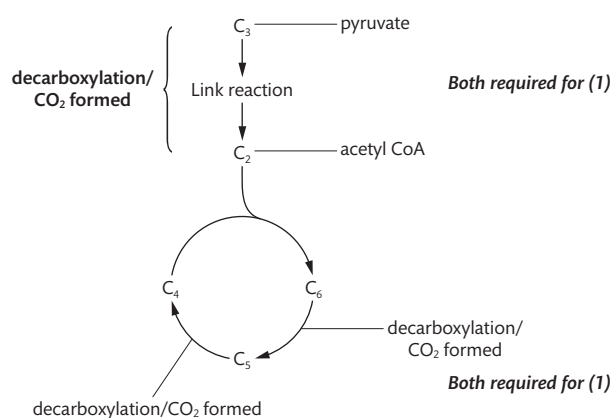
(2 max)

(Total 7 marks)

7 D

(Total 1 mark)

8 (a) (i) and (ii)



(2)

(iii) $\text{NADH} + \text{H}^+/\text{FADH}_2/\text{ATP}$ (or GTP) (1)

(b) matrix of mitochondrion (1)

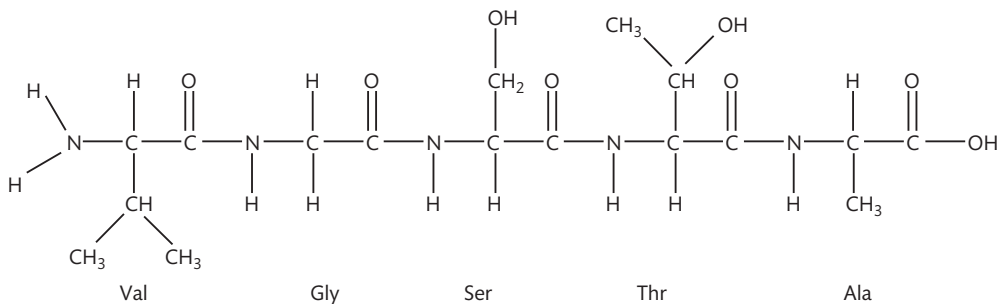
(Total 4 marks)

Challenge yourself

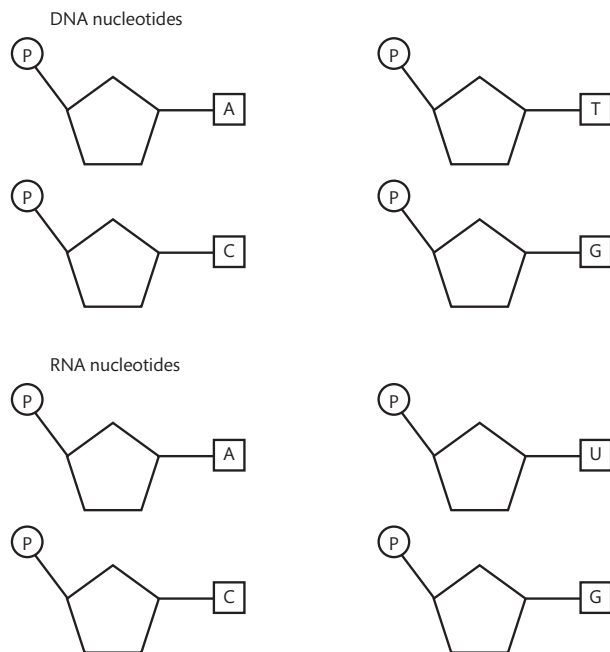
1 In this example no carbohydrates or nucleic acids were directly mentioned. You have probably learned previously that muscle is primarily protein and that explains why the actin and myosin are protein molecules. In addition, virtually all enzymes are proteins and thus trypsin and lipase are proteins as well. The triglyceride molecules are an example of lipid molecules.

3 $79/(1.64 \times 1.64) = 79/1.64^2 = 29.4$. This person is overweight and approaching obese.

7



8



9 (a) 3 and 5.

(b) 5.

(c) 1.

10

Feature	RNA	DNA
Number of strands	1	2
Bases present	A, U, C, G	A, T, C, G
Pentose present	Ribose	Deoxyribose
Name of monomers	Nucleotides	Nucleotides

11 (a) After centrifugation, the band for generation 1 was half-way between where the light band and the heavy bands would be.

(b) In the second generation, half the DNA was where the light strand would be and half was where the intermediate band would be for generation 1.

12 (a) Methionine-proline-arginine-threonine-phenylalanine-proline-serine-proline-glycine.

(b) TACGGGGCGTGC AAAGGTT CGGGGCCC.

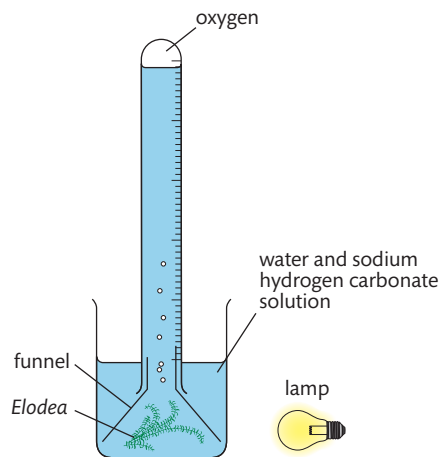
(c) Methionine-serine-arginine-threonine-phenylalanine-proline-serine-proline-glycine (note that only the second amino acid has been changed).

13 (a) As light intensity increases, so does the rate of photosynthesis.

(b) When the enzymes and other proteins involved in photosynthesis are denatured, their shape changes. They are then no longer able to affect the reaction rate in a positive way.

(c) As long as the carbon dioxide concentration continues to increase, an increase in either light intensity or temperature could cause a change.

(d) *Elodea*, a type of pondweed, is very effective to use in the investigation of photosynthetic rates under different conditions. The diagram below represents a typical set-up using this aquatic plant. The bubbles of oxygen produced per minute allow a quantitative measure of photosynthetic rate. Temperature, amount of light, and amount of carbon dioxide can all be tested with this basic set-up.



Labs

2.9 Separation of photosynthetic pigments by chromatograph

- 1 The four pigments have different sized molecules. The pigment that moves the longest distance has the smallest molecule. The charge of molecules also affects the rate of movement and distance moved.
- 2 Leaves from different plants will have different pigments present. This will result in different colours (pigments) on the chromatograph at different distances from the application point.

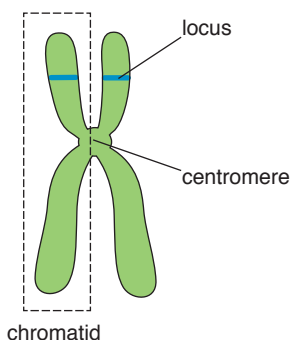
Answers

Chapter 3

Answers are not provided for questions that require individual research or practice.

Exercises

- Alleles are versions of genes. The term 'gene' can be considered to be more general, whereas 'allele' is more specific.
- Answers will vary. Possible suggestions: better vision, better colours for camouflage, wing shape changes to allow better speed or precision in flight.
- Because eukaryotes reproduce using sexual reproduction, half of the genetic material is always from the female parent and the other half from the male parent.
- The drawing should show one or two chromatids as vertical rods, a centromere between the top and bottom arms of the chromatids, and a locus drawn as a line across one of the chromatids.

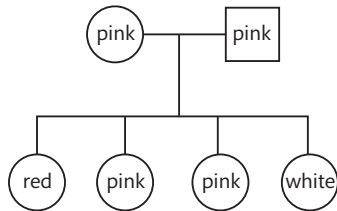


- Because they only have one parent, they only have one chromosome, so they can never be $2n$.
- Women generally have their children at a young age. Even though the risks are smaller, since the total number of babies is higher, the number with Down syndrome will be a bigger number, even though it is a smaller percentage.
- Because the resulting daughter cells only contain half of the genetic material of the parent cells. The number of chromosomes changes from $2n$ to n .
- Because mitosis produces diploid cells, and if such cells were used as gametes, the resulting offspring would have $2n + 2n = 4n$ chromosomes. In that case, the number of chromosomes would double every generation: $4n$, $8n$, $16n$, $32n$, and so on. To maintain the appropriate chromosome number, meiosis is used so that the resulting offspring have $n + n = 2n$ chromosomes.
- For males, sperm cells; for females, egg cells.
- Drawings should be similar to Figure 3.18.
- Because the allele for colour blindness is recessive and sex linked, in order for a woman to be colour blind, she must have two recessive alleles, one on each of her X chromosomes: X^bX^b . In any other case, she would be carrying at least one dominant allele to cancel out the effects of the colour blindness allele. In most populations, it is rare to receive one of these recessive alleles and even more rare to get both alleles for colour blindness. On the other hand, it is much easier for a man to get the condition because there is no locus on the Y chromosome to carry a dominant allele to mask the recessive allele on his X chromosome. As a result, the presence of just one b allele is enough to give him colour blindness.
- The answer should show the Punnett grid for the cross $C^R C^W \times C^R C^W$.

	C^R	C^W
C^R	$C^R C^R$	$C^R C^W$
C^W	$C^R C^W$	$C^W C^W$

- In the top row, one circle and one square should be joined by a horizontal line. They should both be labelled pink. In the next row, showing the F_1

generation, the four offspring plants should show one red, two pink and one white.



The offspring are shown here as all female, but any combination of shapes could be used.

- 14 (a)** $X^H X^h$ for the mother and $X^H Y$ for the father.
- (b)** Girls can be either $X^H X^H$ or $X^H X^h$ and the boys can be either $X^H Y$ or $X^h Y$.
- (c)** Both possible genotypes for the girls give them normal blood clotting. The genotype $X^H Y$ gives a boy with normal blood clotting but $X^h Y$ is a boy with haemophilia.
- (d)** The only carriers are the mother and any daughters with $X^H X^h$. (Males cannot be carriers.)
- (e)** 1 in 4, or 25%.
- 15** Analysis of DNA samples using techniques such as gel electrophoresis cannot be done with only a few strands of DNA. When DNA samples are collected, for example at a crime scene, sometimes only a few cells are found. To obtain enough copies for analysis, the DNA strands must be copied millions of times.
- 16** Typically, the source of stem cells is human embryos. The ethical question is: 'Can we use embryos purely as research tools?' Critics argue that these balls of cells should be treated with respect and dignity because they are of human origin and their natural destiny is to try to develop into baby girls or boys, so using them for another purpose is unnatural and unethical.
- 17** Answers will vary, but both benefits (e.g. a plant's resistance to drought, higher yield) and risks (e.g. consequences of GM pollen escaping, possible allergies) should be explored, and there should be a justification in the answer.

- 18** Answers will vary, but it is generally agreed that the labelling in most countries is insufficient for consumers to make educated choices about the foods they buy. For example, labels could say 'may contain GM soybeans' but it is not clear what percentage could be expected.

Practice questions

- 1** B (Total 1 mark)
- 2** D (Total 1 mark)
- 3** B (Total 1 mark)
- 4** knowledge of location of human genes/position of human genes on chromosomes; knowledge of number of genes/interaction of genes/understanding the mechanism of mutations; evolutionary relationships between humans and other animals; discovery of proteins/understanding protein function/detection of genetic disease; leads to the development of medical treatment/enhanced research techniques; knowledge of the base sequence of genes/study of variation within genome (Total 3 marks)
- 5** two sex chromosomes are X and Y; one sex chromosome inherited from each parent; XX results in female; XY results in male; sex determined by sperm/father; sex-linked genes are those located on the sex chromosomes/usually refers to genes on X chromosome; recessive sex-linked traits appear more frequently in males since they only have one X chromosome; haemophilia is an example of a gene located on the X chromosome/sex-linked; female carriers are heterozygous/ $X^H X^h$; males with haemophilia are $X^h Y$ /normal males are $X^H Y$; sons (of carrier females) have 50% probability of showing the trait (even if father is normal); daughters ($X^h X^h$) of haemophiliac father and carrier mother can be affected/daughters who receive an affected X from each parent will have haemophilia

The points above can be gained by annotated Punnett grids. Candidates may introduce a lettering system for haemophilia genotypes that does not include H and h. Accept other letters for superscripts, but same alphabetical letter should be used throughout, dominant form should appear as upper case letter and recessive as lower case letter. (Total 7 marks)

6 A (Total 1 mark)

7 one gene determines (ABO) blood groups/ one gene for ABO blood groups; genes have different/alternative forms called alleles; there are three alleles (I^A , I^B , and i) of the gene for (ABO) blood groups; (ABO) blood groups are an example (of the effect of) multiple alleles (in this instance three alleles can result in four phenotypes); each individual has two alleles of the gene but only one is passed to offspring; alleles that are co-dominant both affect the phenotype in a heterozygote; (alleles) I^A and I^B are co-dominant; (alleles) I^A and I^B are dominant over i ; i is recessive to I^A and I^B ; (genotypes) $I^A I^A$ and $I^A i$ both give blood group A; (genotypes) $I^B I^B$ and $I^B i$ both give blood group B; (genotype) $I^A I^B$ gives blood group AB; (genotype) ii /homozygous i gives blood group O; example of a cross involving ABO blood groups (Total 9 marks)

8 carrier has (one copy of) a recessive allele; must also have a dominant allele to prevent having the condition/disease;

or

cannot be homozygous dominant or they would not carry the recessive allele; cannot be homozygous recessive or they would have the condition/disease (Total 2 marks)

Challenge yourself

- 1
 - Skin colour: largely genetic, but exposure to sun can change skin colour.
 - Freckles : genetic, but sunlight can make them more pronounced.
 - Number of fingers on each hand: genetic but an accident or disease could cause the loss of digits.
 - Blood type: genetic, although, exceptionally, people given a bone marrow transplant can change blood type.
 - Colour blindness: genetic.
 - Sex: genetic.
 - Ability to digest lactose: genetic.
 - Reflexes: genetic.
 - Type of ear wax (wet or dry): genetic.
 - A scar from an accident: acquired.
 - Ability to speak: genetic, although some psychological or medical conditions might cause mutism.
 - Ability to speak Spanish: acquired.
 - Height: largely genetic, although poor nutrition can prevent people from reaching their full potential height.
 - Personality: some components appear to be genetic, others are acquired and many are a mix of both.
 - Intelligence: this depends on what the definition of 'intelligence' is. Highly debatable.

The man's children would not be born with only one foot. Scientists rejected the idea of passing on acquired characteristics decades ago.

- 2 (a) Asian rice, *Oryza sativa*.
- (b) If viruses are accepted as a species, then it's phiX174. Otherwise it's *E. coli* (type K-12).
- (c) The nematode *Caenorhabditis elegans*.
- (d) Answers may vary but could include the following. For: 'simple' organisms such as *E. coli* that do not have specialized or differentiated cells have a smaller number

of genes as more 'advanced' species such as the fruit fly. Against: we humans like to consider ourselves to be the most 'advanced' species on Earth and yet we have a similar number of genes as a worm and fewer genes than Asian rice. Having said this, it would be difficult for humans to survive in the niches of these other species.

- 3 Answers may vary but if students compare organisms that evolved long ago, such as bacteria, to organisms that evolved more recently, such as plants and animals, they should see a difference.
- 4 This is a girl because the two chromosomes in the 23rd pair are long chromosomes, suggesting that they are both X, which is characteristic of a girl. If there was a long chromosome and a short one, it would be XY for a boy. The anomaly visible in this karyogram is that there are three chromosomes in the 21st pair instead of two. This can be interpreted as showing Down syndrome.
- 6 The details of a karyogram that would reveal whether or not the child has Down syndrome is the number of chromosomes in the 21st pair: if there are two, the child does not have it, if there are three, the child has it.
- 7 Answers may vary. Possibilities include religious beliefs, family values, personal feelings, financial limitations, availability of special education and care.
- 8 The 23rd pair of chromosomes will show two long chromosomes (XX) if it is a girl, and one long and one short chromosome if it is a boy (XY).
- 9 Answers will vary from country to country and within countries.
- 10 The drawing should look like Figures 3.17 and 3.18.
- 11 Child 2 (C_2).
- 12 Suspect 3 is a perfect match to the DNA found in the blood stain.

Nature of science

3.3 Thanks to such a graph, what advice can doctors give women who wish to avoid this syndrome in their children?

To minimize the risk of having a child with Down syndrome, it is best for the mother to have a child before she is 35 years old, because between the ages of 35 and 40 the risk doubles, and it continues to increase after the age of 40. Having said this, even if a woman has her baby at the age of 44, the risk is about 1 in 166 of having a child with Down syndrome, which is less than a 1% chance.

3.4 When and how did we find out that X-rays were not a safe and healthy way of performing prenatal examinations?

Statistics can be used in scientific investigations for revealing hidden phenomena and can be instrumental in determining causality. Dr Stewart's example shows that, in order to be taken seriously by the scientific community, a study needs to be replicated and similar results need to be found in order for them to be considered valid. Despite convincing evidence, it often takes many years for the scientific community to accept a new development: this is because scientists are sceptical and need more than one study to be convinced. When dealing with statistics, it is important to remember the GIGO rule: garbage in, garbage out. If erroneous or outdated numbers are plugged into a statistical analysis, the results will also be erroneous or outdated. Instead of accepting statistics on face value, scientists often ask questions such as 'Where do these numbers come from? How were they calculated? Have all the data been considered or has there been some cherry-picking? As to the ethical nature of the doctors' actions, there are arguments both ways, but if we invoke the precautionary principle, they should not have been exposing children to X-rays before proving that the radiation was harmless.

Answers

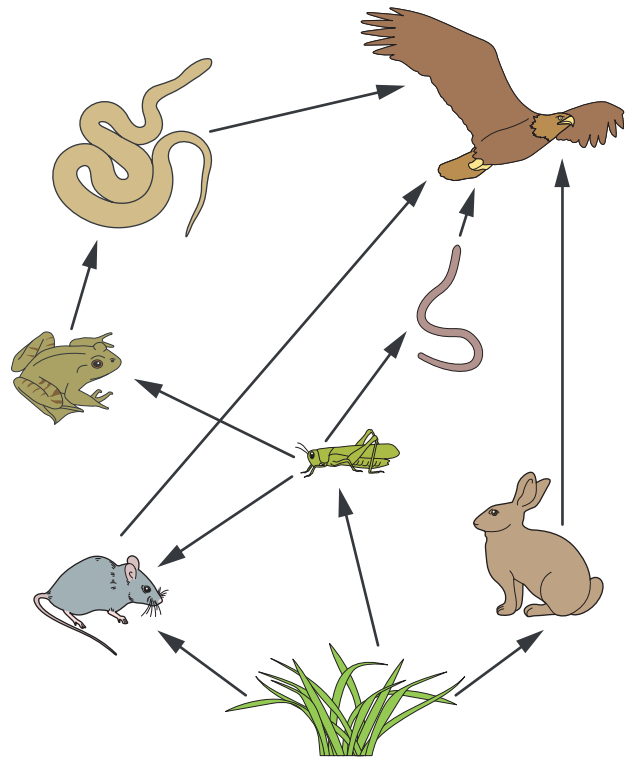
Chapter 4

Answers are not provided for questions that require individual research or practice.

Exercises

- 1 Habitat refers only to the place or the environment where an organism lives, whereas an ecosystem refers to the place and to the other organisms living there as well.
- 2 Decomposers are instrumental in returning nutrients to the environment so that they are available for other organisms.
- 3 Answers will vary. Autotrophs can be any plant species that produces something we eat, such as grains, fruits, and vegetables. Heterotrophs can be any animal species that produces something we eat, or fungi that we eat.
- 4 (a) Grassland ecosystem: producer → primary consumer → secondary consumer → tertiary consumer → quaternary consumer/ top predator
(b) River ecosystem: producer → primary consumer → secondary consumer → tertiary consumer
(c) Marine ecosystem: producer → primary consumer → secondary consumer → tertiary consumer → quaternary consumer/ top predator

- 5 The drawing should reflect the relationships between all seven organisms, with grass at the bottom and the hawk at the top.



- 6 Secondary consumer
- 7 (a) 1965 = 320 p.p.m., and 2001 = 370 p.p.m.
(b) 15.6% change over the 36-year period. The calculation is $((370 - 320)/320) \times 100$.
(c) The fluctuations are because of the seasons in the northern hemisphere. Summer = intense photosynthesis, so less CO_2 in the air; winter = reduced photosynthesis, so more CO_2 in the air.
(d) Hawaii, because it is far from urban centres that might falsify the data with high levels of pollution.
- 8 From carbon dioxide dissolved in water, and hydrogen carbonate ions.

- 9 (a) Peat.
(b) Coal.
(c) Kerogen.
(d) Natural gas.
- 10 In a garden greenhouse, it is the glass that lets in light but traps heat. On Earth, it is greenhouse gases in the atmosphere that play that role.
- 11 Oxides of nitrogen (NO_x), but they are less of a concern for the greenhouse effect because their concentrations in the atmosphere are more than 1000 times smaller than the carbon dioxide concentrations.
- 12 Answers will vary but could include, for example, using public transport, choosing foods produced locally, insulating your home.
- 13 Coral bleaching is caused when slight changes in the water occur, often because of human activity: temperature increases or acidification of the water because of increased CO_2 levels, for example, contribute to the problem.

Practice questions

- 1 D (Total 1 mark)
- 2 B (Total 1 mark)
- 3 C (Total 1 mark)
- 4 A (Total 1 mark)
- 5 energy flows up from one trophic level to the next (in a community); energy is lost at each stage by waste products/faeces/not all the organism is consumed; most energy is lost through respiration/heat each level on the pyramid is about 10–20% of the size of the one below it/80–90% energy lost between levels; labelled diagram of pyramid of energy (indicating trophic levels) (Total 3 marks)
- 6 D (Total 1 mark)
- 7 CO_2 is a greenhouse gas; increases in CO_2 increase/enhance the greenhouse effect; greenhouse effect is a natural phenomenon

but not its increase; Earth receives short-wave radiation from the Sun; re-radiated from Earth as longer wave radiation/infrared/heat; CO_2 /greenhouse gases trap/absorb longer wave radiation/infrared/heat; global warming happened during same time/period as CO_2 rise; CO_2 concentration correlated (positively) with global temperature/global temperature (causal) link accepted by most scientists; no proof that human-made increases in CO_2 have caused global warming; increases as CO_2 concentration increases (Total 5 marks)

- 8 some human-induced change can be very large/ perhaps catastrophic; those responsible for the change must prove it will cause no harm before proceeding; appropriate (environmental/medical, etc.) example, e.g. companies must immediately reduce emission of greenhouse gases even though proof of human impact on global warming is still debated; is reverse of historical practice/previously those concerned about change had to prove it will do harm to prevent such changes from going ahead/paradigm shift (Total 2 marks)

Challenge yourself

- 1 (a) The water, the rocks, the gases in the atmosphere (notably oxygen and carbon dioxide); minerals in the moose/elk's diet, such as calcium and sodium.
- (b) The trees, the moose/elk, the fish and other aquatic organisms under the water, any non-visible animals and plants in the forest, the microbes (in the water, mud, soil, or living on or in the moose/elk).
- (c) Trees and other plants in the forest, algae and photosynthetic plankton in the water.
- (d) The moose/elk, the fish in the water, mushrooms growing in the forest, soil organisms underground, such as earthworms and mites.

2 Answers will vary, but may include:

Organism	What it depends on	What depends on it
Monkey	The tree for habitat and food	The fruit trees need the monkey for seed dispersal
Frog	The tree for habitat and insects for food	The snake needs the frog for a food source
The tree	Decomposers in the soil to provide nutrients from decaying material	The vast majority of the mammals, birds and insects in the forest need the tree as a resource for something

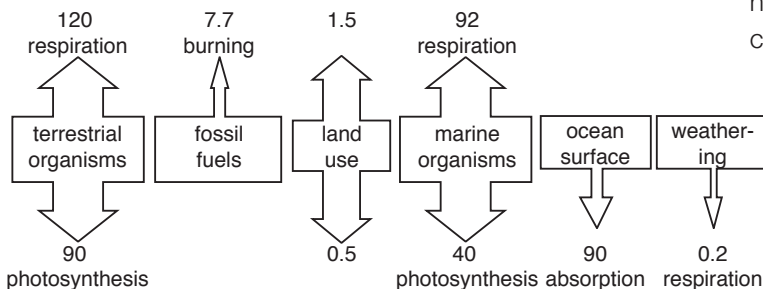
3 (a) Heterotroph.

(b) Heterotroph that is a saprotroph.

(c) Autotroph.

(d) Heterotroph.

4



All quantities are expressed in gigatons of carbon per year (GtC y⁻¹)

5 (a) There appears to be a relatively strong correlation from 18 000 to 10 000 years ago, as there is an increase in both CO₂ and temperature, then both are relatively stable from 10 000 years onwards, with the exception of the last few hundred years when the CO₂ level rises more steeply than the temperature.

(b) Scientists cannot draw a conclusion of causality from a correlation unless they can provide a logical mechanism explaining the causality. As CO₂ is known to be a greenhouse gas that can radiate heat energy back to Earth, there is a mechanism for causality in this case. However, scientists rarely deal in absolutes; preferring to be cautious, they refer to probabilities. The International Panel on Climate Change (IPCC) has declared that global warming is happening, that the recent increase in CO₂ observed in graphs like these is responsible for the warming, and that they are 95% sure the phenomenon is being caused by human activity rather than by any natural fluctuations.

(c) To confirm a hypothesis, scientists often ask for more data. Science involves repeating and verifying. The more data collected by satellites and sea-level probes, of rainfall measurements, ocean temperatures, and air temperatures, the better we can understand how the climate works and how it is changing.

Nature of science

4.4 How do scientists collect data to see climate change?

The Argo float requires GPS satellite positioning and some sort of data-logging program that would collect the date, time, and position at regular intervals. Then these data would have to be transmitted to a research facility, perhaps by radio waves. The satellite photo was taken hundreds of kilometres above the surface and the digital camera's pixels would have to be transmitted back to a research facility on Earth's surface, again probably via radio signals. To understand climate, climatologists need information about sea level, ocean currents, cloud

cover, wind direction, and precipitation, among other data. Feeding this information into computer models helps to understand better the past and present, and therefore project values into the future. CO₂ emissions are measured in climatology stations at various points around the globe, including Hawaii. Being far from industrial activity helps to avoid excessive readings of CO₂ associated with industrialization. As volcanoes give off CO₂ and as the Hawaiian islands are volcanoes, the active ones are monitored and any CO₂ that is suspected as coming from volcanic activity is subtracted from the data. Although some stations may have variations regarding how much the carbon dioxide levels are rising, they all agree that levels are increasing globally.

Answers

Chapter 5

Answers are not provided for questions that require individual research or practice.

Exercises

- 1 Evolution is defined as the process of cumulative change in the heritable characteristics of a population.
- 2 Life was very different 500 million years ago, compared with today; many species have gone extinct; many species considered to be top predators today did not exist at the time of the dinosaurs or before; organisms have certain adaptations that evolved a very long time ago and others have adaptations that have evolved very recently, showing that life forms have increased in complexity. Answers such as 'organisms tend towards perfection' or 'get better over time' are not considered to be scientifically sound statements.
- 3 Farmers and animal breeders noticed that when they selected the members of their breeding population that had the most desirable characteristics over many generations, they ended up with plants and animals that were very different from the original varieties. The plants and animals found on farms today are very different from their ancestors; this is evidence of evolution. The driving force is artificial selection rather than natural selection, however.
- 4 Answers may vary but could include Darwin's Galapagos finches and the lemurs of the Comoro Islands and Madagascar.
- 5 Meiosis and sexual reproduction.
- 6 Artificial selection is when humans such as farmers, breeders, geneticists, or gardeners decide which traits will be present in future generations of animals and plants by only allowing parent organisms who possess those traits to reproduce. In natural selection, natural environmental pressures determine which traits are successful and which are not (e.g. prolonged lack of rainfall will select those plants that are resistant to drought, and the rest will die of dehydration).
- 7 The dark speckles on the eggs are good camouflage in the nest on the ground. If brightly coloured eggs were produced, they would be more visible to predators from a distance. As a result, they would be more likely to be eaten. This means the chicks inside would never have the chance to grow up and reproduce. So the genes for the inappropriate egg colour would not be passed on to the next generation.
- 8 The first spraying will kill most insects in the population but a few will be naturally resistant. Those few survive and reproduce. The offspring will contain a large percentage of resistant insects.
- 9 Three domains = Eubacteria, Archaea and Eukaryote.
 - (a) Archaea.
 - (b) Eukaryote.
 - (c) Eukaryote.
 - (d) Eubacteria.
- 10 Viruses do not reproduce in the way any members of the three domains do, they do not have similar structures (e.g. no cell membrane or organelles).

11

	Bryophyta	Filicinophyta	Coniferophyta	Angiospermophyta
Physical characteristics	Vascular	Non-vascular	Vascular woody stems Leaves are needles	Vascular flowers Fruit
Named examples (may vary)	Moss	Fern	Pine	Rose

- 12 Primate.
- 13 Answers will vary but the best way to test a dichotomous key is to get another person to identify the objects using the key. If they get stuck or misidentify the object, the key does not work.
- 14 Analogous = similar function but not necessarily the same structure, whereas homologous = similar structure but not necessarily the same function. Another major difference is that analogous structures are not evidence of a common ancestor, whereas homologous structures (such as the pentadactyl limb) are considered evidence of common ancestry.
- 15 (a) One difference (amino acid 104).
 (b) Four differences (amino acids 111, 112, 114, and 116).
 (c) The horse's sequence because there are more differences/fewer similarities in the amino acid sequence.

Practice questions

- 1 A (Total 1 mark)
- 2 varied members of a single species occupy a variety of niches/migration of a species to an area with a variety of niches; natural selection/selection pressure will be different in various niches causing adaptation of groups to the varied niches; results in many species from one ancestral species; reproductive isolation enhances adaptive radiation; adaptive radiation results in speciation (Total 3 marks)
- 3 D (Total 1 mark)
- 4 natural selection (*in correct context*); better-adapted individuals survive/more likely to survive; more reproduction/genes passed on by better adapted individuals; name of species; (*accept even if remainder of answer is invalid*) description of original/decreasing phenotype; type of environmental change that led to

evolution; consequence of environmental change description of new/increasing phenotype; genetic basis of phenotypes; reason for new phenotype being better adapted; detail of reason for adaptedness of new phenotype

The following has been provided as an example answer.

Great tit; bird that lays its eggs in spring; global warming/climate change; more caterpillars (on trees) in early spring; laying eggs earlier in spring; time of egg laying is (partly) genetically controlled; eggs laid early hatch at start of period of greatest food abundance; more young can be fed/young grow faster/fewer deaths

(Total 8 marks)

5 A (Total 1 mark)

6 D (Total 1 mark)

7 A is most similar to B; A is equally similar to C and D; A is least similar to both C and D (Total 2 marks)

8 analogous: similar structures but different (evolutionary) origins/different basic structure but same function; e.g. vertebrate and invertebrate eyes/insect and human legs

Accept any other valid example. (2 max)

Homologous: structures are of similar origin/same basic structure but different functions; e.g. pentadactyl limbs in vertebrates

Accept any other valid example. (2 max)
 (Total 4 marks)

9 methods used to prepare cladograms use a different approach from traditional classification/taxonomy; show ancestral relationships; reflect how recently two groups shared a common ancestry; cladograms are (objective/accurate because they are usually) based on molecular differences; they should be considered as a good complement to traditional classification (Total 2 marks)

10 all four organisms have vertebrae; shark is the oldest/furthest from human/other examples

of relationships between the four organisms;
human only one with all four characteristics;
appearance of legs separated others from shark;
appearance of mammary glands, separated

kangaroo and human from bullfrog; appearance
of placenta, separated human from kangaroo;
both kangaroo and human are mammals
(Total 3 marks)

Challenge yourself

1 (a)

Characteristic	Bat	Bird	Human	Horse	Dolphin	Turtle
Number of digits (fingers)	5	3	5	1	5	5
Description of phalanges (finger bones)(short/long, wide/narrow)	Very long and thin	Short	Long and thin	Long and wide	Wide	Short
Type of locomotion that the limb is best adapted for	Flight	Flight	Grasping rather than locomotion	Running	Swimming	Swimming and walking

(b) Birds and horses have lost digits from the original 5-fingered common ancestor, presumably for different reasons. It can be hypothesized that wings that had more fingers were heavier and slowed down the birds, whereas natural selection would have favoured mutations of fewer fingers, making the wings lighter. Having no fingers at all would be a disadvantage, however, as wings need some support. Another reason is that the hollow cartilage in the feathers plays some of the role of support and so five fingers are not necessarily needed for support. Fossils of ancient horse skeletons contain more than just one digit on each leg. It can be hypothesized that running through tall grass to escape from a predator might be slowed down by having multiple,

heavy digits. Horses born with fewer digits could run faster and escape more easily, increasing their ability of surviving and passing on the genes for fewer digits to the next generation. Also, having one long finger (or in this case, a toe), can generate more torque to run faster than having multiple short toes.

(c) The salamander has similar bone structures to the other animals in terms of carpals, metacarpals, and phalanges, and the proportion of length to width is comparable to turtles and humans. However, it has lost a digit on each forelimb over the course of its evolution. Salamanders are amphibians and use their forelimbs for walking, swimming, and wading.

Answers

Chapter 6

Answers are not provided for questions that require individual research or practice.

Exercises

- 1 Carbohydrates: polysaccharides like starch will be digested into disaccharides and monosaccharides; disaccharides will be digested into monosaccharides. Lipids: triglyceride lipids will be digested into glycerol and three fatty acids. Proteins: polypeptides will be digested into individual amino acids (20 types).
- 2 Answers will vary, but should include most or all of the following: mouth, oesophagus, stomach, small intestine, capillary in villus, hepatic portal vein, liver, hepatic vein, heart, capillaries, muscle cell.
- 3 The pancreas produces three important digestive enzymes: amylase, trypsin, and lipase (which catalyse starch, protein, and lipid digestion, respectively). All of these secretions are added to the first part of the small intestine via a duct.
- 4 Right atrium, right atrioventricular valve, right ventricle, right semilunar valve, pulmonary artery, (lung capillary bed), pulmonary vein, left atrium, left atrioventricular valve, left ventricle, left semilunar valve, aorta, (body capillary bed), vena cava, and back to the starting point of the right atrium.
- 5 The hole between the atria allows blood in the two atria to mix together. The blood coming in to the right side of the heart is already a mix of oxygenated and deoxygenated blood because the oxygenated blood from the placenta comes back to the right side of the heart in the venous circulation (mixed with the deoxygenated blood from the foetal body). This pattern has evolved to account for the lack of oxygen and carbon dioxide exchange in the foetal lungs (a foetus does not breathe) and allows some of the blood to go to the lungs to oxygenate lung tissue and some to take a short cut to get to body tissues (through the hole).
- 6 Heart valves open and close based on blood pressure differences on either side of the valve.

Example: semilunar valves will only open when the ventricles build up enough pressure to exceed the existing pressure in the aorta (and pulmonary artery). When the pressure exerted by the ventricle begins to drop, and the pressure in the two exiting arteries becomes greater, the valves will close.
- 7 The severity of symptoms depends on two primary factors:

The tissue type that is the target tissue of a virus: a virus infecting nervous system tissue would be predicted to create more severe symptoms than one that infects mucus membrane tissues.

How quickly the virus replicates, resulting in more or less time for the immune system to respond.
- 8 A non-specific immune response is a response to something that is considered to be 'foreign' or 'not-self' but it is not actually identified from a molecular perspective. A specific immune response involves recognition of one or more specific antigens, and the immune response is specific to those antigens, including, but not limited to, the production of antibodies that bind to that antigen(s).
- 9 The answer is nothing. A virus has no metabolic activity whatsoever when it is not inside a host cell.
- 10 In the early years of the progression of the disease, many people associated AIDS with homosexuality, and there was virtually no knowledge of the disease being transmitted by heterosexual contact. Discrimination against a homosexual lifestyle prevented many governing bodies from allocating funds to research the cause, prevention, and possible cure for the disease.

- 11** The answers are complex. First, nicotine is addictive. The easiest way to stop the craving for nicotine is more nicotine. The craving will eventually stop, but many people cannot make it through the time period necessary before it does stop. In addition, smoking becomes a behavioural 'habit': many people smoke because for a long time that is what they have done in certain situations. Having friends that also smoke makes it even more difficult to stop. However, it can be done: many people have successfully stopped.
- 12** Alveoli provide a huge surface area for gas exchange, much bigger than if lungs had evolved as simple 'bags'. Each alveolus is only a single cell thick and the primary cells that allow diffusion (type I pneumocytes) are very thin. Type II pneumocytes secrete a solution that acts as a surfactant that keeps alveoli walls from sticking together. Lastly, each alveolus is always very near to a pulmonary capillary bed for easy exchange of gases.
- 13** Muscles can only do work when they contract; therefore they work in antagonistic pairs for the two movements needed for ventilation. One set of muscles is involved in inspiration and another set in expiration.
- 14** Myelinated neurones have a myelin sheath surrounding their axon. The myelinated areas are interspersed with areas without myelin called nodes of Ranvier. Any action potential moving along this axon is able to skip from one node of Ranvier to the next. The myelin sheath acts as an insulator, and the electric potential can be sensed because of the potential differences within the cytoplasm between the nodes of Ranvier. These nodes act as recharging stations for the action potential. In summary, the big advantage is a greater speed of conduction compared with a non-myelinated axon.
- 15** The threshold potential.
- 16** c – e – a – f – b – d
- 17** Insulin: decreases blood glucose.
Glucagon: increases blood glucose.
Thyroxine: increases metabolic rate.
Leptin: inhibits appetite.
Melatonin: controls circadian rhythm (24-hour cycle).
- 18** FSH (and LH) causing an increase in oestrogen, which in turn causes an increase in FSH (and LH). Positive feedback continues until ovulation occurs.
- 19** After ovulation, progesterone is produced by the newly formed corpus luteum. Progesterone (and oestrogen) at high levels inhibits GnRH production, and thus inhibits FSH and LH production.

Practice questions

- 1** villus intestinal wall has many folds to increase surface area (: volume ratio); surface of villus close to blood vessels so materials can easily diffuse; surface of villus close to lymph vessels so lipids can be easily absorbed; greater surface area related to greater rate of diffusion; villus wall consists of single layer of cells
Do not accept microvilli: not visible in diagrams.
(Total 3 marks)
- 2** Award [1] for every two of the following structures clearly drawn and labelled correctly: mouth; oesophagus; stomach; small intestine; large intestine/colon; anus; rectum; sphincters; salivary glands; liver; pancreas; gall bladder
(Total 4 marks)
- 3** (for information on arteries) thick wall/elastic fibres to help withstand the high(er) pressure; outer fibrous coat prevents artery from rupturing under the high pressures; lumen small compared to wall thickness to maintain high pressure; except lumen large near the heart to conduct

a large volume of blood; valves in aorta and pulmonary artery to prevent back flow into ventricles in diastole; layers of (smooth) muscle to allow arteries to contract/elastic recoil; allows the pressure to be altered (vasoconstriction and vasodilation) (3)

(for information on veins) lumen always large in relation to diameter; thin wall/more collagen and fewer elastic fibres (than arteries) since pressure low(er); very little muscle since not needed for constriction; valves to prevent back flow between pulses (3)

(for information on capillaries) no muscle/elastic tissue since pressure very low; endothelial layer one cell thick to allow permeability/diffusion of chemicals/tissue fluid; small diameter leads to exchange; some fenestration/pores to allow rapid diffusion; no valves since pressure very low (3)

(Total 9 marks)

- 4 antibiotics block specific metabolic pathways/cell wall production in bacteria; viruses reproduce using the host cell metabolic pathways; (host cell) pathways are not affected by antibiotics; viruses do not have metabolic pathways

(Total 3 marks)

- 5 A (Total 1 mark)

- 6 A (Total 1 mark)

- 7 nerve impulse reaches presynaptic button/membrane; calcium ions/ Ca^{2+} enter presynaptic neurone/knob; vesicles with neurotransmitter/acetylcholine release contents; neurotransmitter diffuses across synapse/synaptic cleft; binds to receptors on postsynaptic neurone/membrane; sodium ions/ Na^+ enter postsynaptic neurone/sodium channels open; depolarization/action potential/nerve impulse (in postsynaptic neurone); calcium ions/ Ca^{2+} pumped back into synaptic cleft/synapse; neurotransmitter broken down

(Total 6 marks)

Challenge yourself

- 1 [starting with blood entering the right atrium] right atrium → right atrioventricular valve → right ventricle → right semilunar valve → pulmonary artery (to lung capillary) → pulmonary veins → left atrium → left atrioventricular valve → left ventricle → (to body capillary) → return to right atrium. When checking answer for oxygenated and deoxygenated blood, uncover bottom diagram: blue arrows indicate deoxygenated blood and red arrows indicate oxygenated blood.
- 2
 - When a person is at his or her resting heart rate, the SA node is initiating each heart beat and thus determines the heart rate. The SA node sends an impulse that spreads out over both atria and results in atrial systole. In addition, the AV node senses this impulse and delays for approximately 0.1 seconds and then sends out an impulse that initiates both ventricles to undergo a contraction.
 - When a person is exercising, their increased rate of cell respiration leads to an increase in carbon dioxide in their blood. This increase in carbon dioxide is sensed by chemoreceptors in the medulla oblongata and results in action potentials being sent via the cardiac nerve (a cranial nerve). The cardiac nerve carries the impulses to the SA node, which results in a proportional increase in heart rate.
 - When the exercise level decreases or stops, another cranial nerve called the vagus nerve carries impulses to the SA node to lower the heart rate until the rate returns to its myogenic level.
- 3 Erythrocyte in capillary bed adjacent to an alveolus → venule (smallest vein) → larger and larger veins → one of the pulmonary veins → left atrium → left ventricle → aorta → smaller and smaller arteries → arteriole (smallest artery) → body capillary bed (in muscle, etc.) → venule

→ larger and larger veins → inferior or superior vena cava → right atrium → right ventricle → pulmonary artery → smaller and smaller arteries → arteriole → back to another capillary bed adjacent to an alveolus.

- 4
- 1 The volume of the thorax decreases.
 - 2 The pressure inside the thorax increases.
 - 3 The lungs decrease in volume because more pressure is exerted on them.
 - 4 The pressure inside the lungs increases.
 - 5 Air is forced out of the lungs because of the increased pressure inside the lungs.
- 5
- (a) The area of the membrane just preceding the measured area must have just undergone an impulse (action potential). If this was a myelinated axon, this area may have been in the preceding node of Ranvier.

- (b) It must have been at one of the nodes of Ranvier.
- (c) Because an impulse is self-propagating and this axon is myelinated, the next area will be the next node of Ranvier.
- (d) In reality, the sodium/potassium pump never does stop working. The pump would have ions in positions for optimal 'pumping' at: 9–12 milliseconds for the left side impulse 30–32 milliseconds for the middle impulse 41–44 milliseconds for the right side impulse
- (e) The neurone would not be able to keep up with all of the sensory information coming in, as it would not be ready to send another impulse until it goes through a complete cycle of events, including restoring the ions back to their positions characteristic of the resting potential.

Answers

Chapter 7

Answers are not provided for questions that require individual research or practice.

Exercises

- 1
3' _____ 5'
5' _____ 3'
(The two strands have different carbons of deoxyribose exposed at their ends.)
- 2 If DNA is wrapped tightly around the histone molecules, it is in a nucleosome and is not available for helicase to break its hydrogen bonds and begin the process of transcription. Only the strands of DNA between the beads are available for code transfer to RNA.
- 3 Mitochondria and chloroplasts also possess DNA.
- 4 The energy source for DNA replication is the two phosphates that occur on the end of each deoxynucleoside triphosphate that is added to the elongating DNA chain.
- 5 The process of replicating the very long chromosomes would be so slow that the cell would be involved with replication during most of the cell cycle and would not be able to carry out the normal cell processes.
- 6 Only one primer is needed on the leading strand. However, the lagging strand requires a primer for the beginning of each Okazaki fragment that forms at the replication fork.
- 7 Using the antisense strand as the basis for this answer, the transcription bubble is moving towards the 5' end of the strand.
- 8 Eukaryotic mRNA requires processing because it contains introns (non-coding sections). The introns are removed before the mature mRNA transcript moves out of the nucleus on its way to the ribosomes. Prokaryotic mRNA has no introns.
- 9 The gene is most likely to be inactive with very little, if any, of that protein being produced.
- 10 Identical twins or individuals produced from the same fertilized egg.
- 11 mRNA carries the message from the DNA of the nucleus to the ribosomes of the cytoplasm. tRNA carries amino acids to the mRNA–ribosomal complex for assemblage into a protein. rRNA structurally makes up more than 50% of the ribosomes.
- 12 If there are polysomes, there are more proteins being assembled. This allows the cell to satisfy protein needs much more quickly.
- 13 Your drawing should look like Figure 7.14.
- 14 The primary level of protein organization refers to the amino acid sequence. The amino acid sequence is the source of the types of weak bonds and electrical forces that determine the other levels of protein organization.
- 15 The prosthetic or non-polypeptide group.
- 16 methionine(start)–alanine–arginine–isoleucine–phenylalanine–stop

Practice questions

- 1 A (Total 1 mark)
- 2 B (Total 1 mark)
- 3 B (Total 1 mark)
- 4 (a) (i) phosphate (1)
(ii) covalent/phosphodiester (1)

- (b) only the antisense strand is transcribed/the antisense strand is transcribed to mRNA and the sense strand is not transcribed/has the same base sequence as mRNA (with uracil instead of thymine) (1)

To award [1], reference must be made to both strands and transcription.

(c)

Prokaryotic DNA	Eukaryotic DNA
circular	linear
in cytoplasm/nucleoid region	enclosed in nuclear membrane/in nucleus
naked	associated with proteins/histones
plasmids	no plasmids
both prokaryotic and eukaryotic DNA consist of a double helix of (deoxy)nucleotides/phosphate, deoxyribose and base/A, T, C, and G	

(2 max)

Award marks for paired statements only. Answers do not need to be shown in a table format.

(Total 5 marks)

- 5 B (Total 1 mark)
6 B (Total 1 mark)
7 C (Total 1 mark)

- 8 (a) structure–collagen; transport–transferrin/haemoglobin; enzyme/catalyst–lysozyme; movement–actin/tubulin; hormones–insulin; antibodies–immunoglobulin; storage–albumin

Accept any other valid function of proteins with a named example. For example, sodium–potassium pump, but do not accept simply 'in membranes' without a clear function.

To award [4 max], responses need a function of protein and a named example. Only accept the first four answers. (4 max)

- (b) made of protein; made of rRNA; large subunit and small subunit; three tRNA

binding sites; Aminacyl/A, Peptidyl/P and Exit/E ; mRNA binding site (on small subunit); 70S in prokaryotes/80S in eukaryotes; can be free/bound to RER (in eukaryotes) (6 max)

- (c) RNA polymerase; (polymerase number is not required) binds to a promoter on the DNA; unwinding the DNA strands; binding nucleoside triphosphates; to the antisense strand of DNA; as it moves along in a 5'→3' direction; using complementary pairing/A–U and C–G; losing two phosphates to gain the required energy; until a terminator signal is reached (in prokaryotes); RNA detaches from the template and DNA rewinds; RNA polymerase detaches from the DNA; many RNA polymerases can follow each other; introns have to be removed in eukaryotes to form mature mRNA (8 max)

(Plus up to [2] for quality)

(Total 20 marks)

9 C

(Total 1 mark)

Challenge yourself

- Their position can be tracked because of radioisotopic decay. Also, sulfur occurs in protein but not DNA, while phosphorus occurs mostly in DNA and not as much in protein.
- The DNA.
- No.
- DNA is the genetic material because nearly all the radioactivity found in *E. coli* after the transfer was from ³²P, the marker found in DNA. There was no ³⁵S present.
- (a) The presence of one 'gata'.
(b) There could be more or fewer sequences of 'gata' in the bases present. There could also be changes within the 'gata' sequence.
(c) When individuals are identical twins.

6 C A G C G A T T A C G C T C A G G A T C A

The bottom C is the smallest and first nucleotide because it migrated the greatest distance in the figure.

7 (a) Genes in nucleosomes are not accessible to the transcription process.

(b) The DNA strands that exist between adjacent nucleosomes.

(c) The section of DNA coding for a specific protein (gene) would have to be moved off the nucleosome before it could be transcribed.

Answers

Chapter 8

Answers are not provided for questions that require individual research or practice.

Exercises

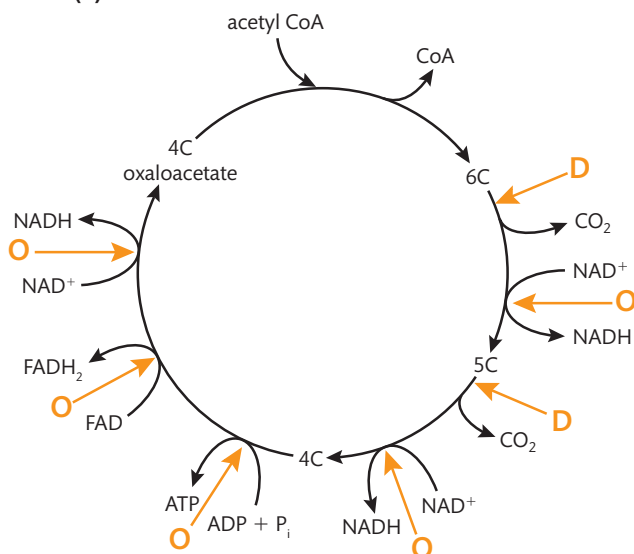
- 1 The bonds and general shapes are specific for both the enzyme and the substrate. If the substrate does not have a compatible shape and appropriately positioned electrical forces, the substrate will not fit the active site of the enzyme.
- 2 In competitive inhibition, the competitor molecule combines with the active site directly. This prevents the substrate from combining. In non-competitive inhibition, the active site is not bound by the outside molecule. In this case, the molecule combines with an alternative site on the enzyme, causing a conformational change resulting in decreased enzyme function.
- 3 The most efficient control of a metabolic pathway involving end-product inhibition would occur at the enzyme between the beginning substrate of the pathway and the first intermediate product.
- 4 12 ATPs are generated by the Krebs cycle and the electron transport chain. A further 3 ATPs are generated from the NADH formed in the link reaction. So a total of 15 ATPs would be produced (not 18 because there is no glycolysis reaction to consider in this question).
- 5 Striated muscle cells are very active. They allow all voluntary motion. It takes large amounts of ATP to allow the movements muscles have the function of providing.
- 6 NAD allows production of more ATP because it enters the electron transport chain at an earlier point than FAD.
- 7 The result would be fewer ATPs produced because the hydrogen ions would not be forced to move through the channels of ATP synthase. It is the movement of hydrogen ions through these channels that allows the phosphorylation of ADP.
- 8 ATP synthase allows a faster reaction bringing about phosphorylation of ADP. If this enzyme did not exist, the process of ATP production would be extremely slow.
- 9 Photosynthesis allows the production of chemical bonds in organic molecules, especially glucose. The process of photosynthesis does not release ATP for the cell to use. Photosynthesis occurs in chloroplasts. Respiration catabolizes glucose so that chemical bonds are broken and energy in the form of ATP is released to the cell for work to be done. Respiration occurs in mitochondria. Because of this, a plant must have both chloroplasts and mitochondria.
- 10 The greater the number of different pigments a leaf has, the greater the absorption of light at more wavelengths. The result is a higher rate of photosynthesis.
- 11 Photosystem II results in the production of ATP. Photosystem I results in the production of NADPH. Photolysis of water is associated with Photosystem II, thus allowing the release of oxygen to the atmosphere.
- 12 There are very many higher evolved plants (providing a very high biomass) that carry out photosynthesis in the world. With the large biomass comes very large numbers of cells and chloroplasts. Most of these cells carry out photosynthesis. To carry out the light-independent reaction, these cells must have RuBP carboxylase. For these reasons the statement is very possibly true.
- 13 ATP and NADPH are produced in the light-dependent reaction. In order for the Calvin cycle of the light-independent reaction to occur, both of these products are essential. ATP provides energy, while NADPH enables the reduction of various compounds.

Practice questions

- 1 D (Total 1 mark)
- 2 C (Total 1 mark)
- 3 C (Total 1 mark)
- 4 A (Total 1 mark)
- 5 C (Total 1 mark)
- 6 A (Total 1 mark)
- 7 C (Total 1 mark)
- 8 D (Total 1 mark)
- 9 A (Total 1 mark)
- 10 B (Total 1 mark)

Challenge yourself

1 (a)



- (b) Decarboxylation is evident because the cyclic intermediate compound lost a carbon. Also, it is evident because a carbon dioxide is released at each of the two sites.
- (c) Oxidation is evident because reduction occurred to form NADH from NAD, FADH₂ from FAD, and ATP from ADP + P_i. Whenever oxidation occurs, reduction must also occur.

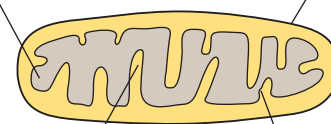
2

Matrix that contains the enzymes for the link reaction and Krebs cycle

Outer membrane compartmentalizes the mitochondrion from the cytosol

Space between inner and outer membranes that allows a high concentration for protons to accumulate for chemiosmosis, intermembrane space

Inner membrane folds to form cristae that increase surface area for reactions and contain ATP synthase and other proteins for the electron transport chain



3 (a) A

(b) C

(c) D

(d) B

(e) B, D. They contain the pigment chlorophyll, which makes up part of the photosystems.

(f) The cyclosis will result in more chloroplasts being exposed to the light source. This would increase the photosynthetic process.

Labs

8.3 Experiment to demonstrate electron transfer in chloroplasts

- 1 The test tube with unboiled chloroplasts covered with aluminium foil to keep out light.
- 2 NADP.
- 3 The electrons come from the photolysis of water.
- 4 Darkness resulted in no reaction occurring.
- 5 The high temperatures of boiling resulted in the proteins and enzymes involved in this reaction being denatured. The result was no reaction.

Answers

Chapter 9

Answers are not provided for questions that require individual research or practice.

Exercises

- 1 It is essential to leave some original soil on the roots as this means the root hairs, major absorption structures of a plant, are not disturbed. As a result, they will be able to function in the new location.
- 2 Lack of water to a plant will decrease turgor pressure within the plant cells thus resulting in wilting.
- 3 Stomata are openings through which carbon dioxide and oxygen gases flow as the process of photosynthesis occurs. Any time these structures are open gases are capable of entering and exiting the leaf. Molecules of water are also capable of exiting the plant via the stomata. This results in transpiration.
- 4 When mineral ions are brought into the plant by active transport, a higher level of solutes (hypertonic condition) exists within the root hairs and epidermal cells of the root. Because of the high solute concentration, there is a relatively low water concentration compared with the surrounding soil. Thus, water moves passively into the root cells by osmosis.
- 5 A seed is a source when it first begins germination. At this time, it is providing nutrients to the early plant. The seed acts as a sink when it is being formed in the ovary of the flower. During this time, nutrients are being deposited in the seed.
- 6 Veins need to be relatively close together so that water and nutrients can easily pass to and from them in the plant tissues. Water movement between the phloem and xylem is especially important in sucrose transport.
- 7 Lateral growth would be greatly increased. In many plants this increases yields. Some tomato plant varieties will show increased yield of tomatoes when the apical meristem is removed early in plant growth.
- 8 Auxin acts on repressor proteins to cause previously inactive genes in a cell to become active.
- 9 Plants can continue to grow because of undifferentiated cells in their meristems. There is not a definite limit to their size.
- 10 Roots are negatively phototropic and stems are positively phototropic in most plants.
- 11 Auxin efflux pumps pump auxin out of cells by active transport to aid auxin transport from cell to cell. These are especially active during phototropic responses.
- 12 Dandelion seeds, for example, are very light. They also have parachute-like structures that allow them to be carried long distances in the wind.
- 13 Oxygen is necessary for the aerobic respiration that must occur in the seed to allow embryo germination. Large amounts of ATP are necessary for germination.
- 14 It was the structure through which the pollen tube entered the ovule to bring about fertilization.
- 15 Plant growers can create artificial short days at times of the year when the days are long. This is done by covering the plants with an opaque material for 12-15 hours per day. This is done until the flower buds start to show some colour.
- 16 Pollinators are in trouble worldwide because of chemical pollution, disturbance of natural habitats, introduced and invasive plant and animal species, and diseases and parasites.

Practice questions

- 1 B (Total 1 mark)
- 2 D (Total 1 mark)

3 C (Total 1 mark)

4 C (Total 1 mark)

5 (a) water has a high specific heat capacity; a large amount of heat causes a small increase in temperature; water has a high latent heat of vaporization; a large amount of heat energy is needed to vaporize/evaporate water; hydrogen bonds between water molecules make them cohesive/stick together; this gives water a high surface tension/explains how water rises up xylem; water molecules are polar; this makes water a good solvent

Award 4 max if thermal, cohesive and solvent properties are not all mentioned. (5 max)

(b) xerophytes are plants that live in dry conditions; reduced leaves/spines to prevent water loss (by transpiration); rolled leaves to prevent water loss/stomata on the inside/sunken stomata; thick waxy cuticle/hairs on leaves to prevent water loss (by transpiration); reduced stomata to prevent water loss (by transpiration)/stomata on one side of leaf; deep/widespread roots to obtain more water; special tissue for storing water; take in carbon dioxide at night/CAM plant to prevent water loss (4 max)

(Total 9 marks)

6 (a) transpiration is water loss (from plant) by evaporation; flow of water through xylem from roots to leaves is the transpiration stream; evaporation from spongy mesophyll cells; replaced by osmosis from the xylem; (diffusion of water vapour) through stomata; water lost replaced from xylem/clear diagram showing movement of water from xylem through cell(s) (walls) to air space; water pulled out of xylem creates suction/low pressure/tension; transpiration pull results; water molecules stick together/are cohesive; due to hydrogen bonding/polarity of water molecules; xylem vessels are thin

(hollow) tubes; adhesion between water and xylem due to polarity of water molecules; creates continuous column/transpiration stream (7 max)

(b) flowering affected by light; phytochrome; exists in two (interconvertible) forms/ P_{fr} and P_r ; P_r (red absorbing/660 nm) converted to P_{fr} (far-red/730 nm absorbing) in red or day light; sunlight contains more red than far red light so P_{fr} predominates during the day; gradual reversion of P_{fr} to P_r occurs in darkness; P_{fr} is active form/ P_r is inactive form; in long-day plants, flowering induced by dark periods shorter than a critical length/occurs when day is longer than a critical length; enough P_{fr} remains in long-day plants at end of short nights to stimulate flowering; P_{fr} acts as promoter of flowering in long-day plants; short-day plants induced to flower by dark periods longer than a critical length/days shorter than a critical value; at end of long nights enough P_{fr} has been converted to P_r to allow flowering to occur; P_{fr} acts as inhibitor of flowering in short-day plants (7 max)

(Plus up to 2 for quality)

(Total 16 marks)

7 (a) I sepal
II ovary /receptacle
III petal (3)

(b) (i) Angiospermophyta/Angiospermophytes/Angiosperms

Do not accept flowering plants. (1)

(ii) confirms the hypothesis; *must be qualified* stigma/anther inside the flower/ring of petals so as visiting animal enters it brushes past them; colourful petals (provide contrast) so that flowers can be seen by animals; (slightly) cone-shaped flowers so animals come in (2 max)

(Total 6 marks)

Challenge yourself

- 1 The central oxygen atom is more electronegative than the two hydrogen atoms. Therefore, the shared electrons in the bonds between the oxygen and the two hydrogen atoms spend more time around the oxygen atom. This creates polarity in the water molecule. The negative regions of the molecule are attracted to positive regions of other molecules, whether the other molecules are water or the molecules of the xylem vessels.
- 2 The leaves are the site of transpiration or loss of water molecules from the plant. As molecules of water are lost from the leaf stomata, a pull on the water in the xylem occurs to draw more water into the leaf. This is the source of the 'tension' that is essential to plant fluid transport.
- 3 These plants have extremely high tensions created in the leaves compared with other plants. This allows them to pull water into the plant against the osmotic gradient. The mangroves actually desalt seawater to meet their water needs.
- 4 Source = A, sink = B.
- 5 Leaves.
- 6 A.
- 7 Sucrose.
- 8 It is passive because no energy is expended on the part of the cells involved. Movement occurs along a hydrostatic gradient.
- 9 If water was compressible, there would not be an increase in hydrostatic pressure at A and movement from source to sink would not occur.

Labs

9.1 A 'living' model to observe water transport in plants

- 1 Transpiration provides the 'pull' at the leaves to move the column of water upwards. Cohesion allows the attraction between water molecules

so that the column of water can be maintained. Adhesion occurs between the molecules of water and the sides of the vessel elements, thus also allowing the maintenance of the column of water.

- 2 This plant has very little lignin present. If more lignin was present, it would not be possible to see the water moving.

9.1 Measurements of transpiration rates using potometers

- 3 The independent variable should be on the x-axis, and the dependent variable on the y-axis.
- 4 Depends on the graph and the variable tested.
- 5 Terms such as directly proportional/related, inversely, proportional/related, no relationship, should be used. Anomalies should be described and explained.
- 6 Many possibilities here. Some include improved maintenance of controllable factors, the use of a gas sensor in a differently designed procedure to measure water loss, and improvements in the apparatus setup.
- 7 This depends on the factor tested. For instance, increasing wind speed increases transpirational rate. Plants on a windy day in nature would need more water uptake to compensate for this greater water loss. Brighter light would increase photosynthesis, requiring the stomata to stay open, increasing water loss and, thereby, greater need of water uptake.

9.2 Identification of xylem and phloem in microscope images of roots and stems

- 8 Xylem.
- 9 No, there appears to be no cytoplasm-filled cells in close proximity to the xylem vessels.
- 10 Yes, the companion cells appear to be normal cells with cytoplasm inside cell walls, and they are close to the sieve tubes.
- 11 Phloem is almost always oriented towards the exterior of the root or stem. In some root cross-sections, the phloem is in areas outside an interior xylem area, as shown in this diagram.

3

(a)
$$\begin{array}{cc} \text{T} & \text{E} \\ \hline \text{t} & \text{e} \end{array}$$

(1)

- (b) unenclosed seeds, starchy and tunica present, sugary/

$$\begin{array}{cc} \text{T} & \text{e} \\ \hline \text{t} & \text{e} \end{array} \text{ and } \begin{array}{cc} \text{t} & \text{E} \\ \hline \text{t} & \text{e} \end{array} \text{ (both needed)}$$

(1)

- (c) crossing over; between non-sister chromatids (in prophase I); results in exchange of alleles/change in linkage groups; so some gametes are Te or tE; (linkage notation not expected) test cross expect ratio of two phenotypes/correct Punnett grid showing test cross; but instead get four phenotypes with smaller percentage of recombinants

(1)

(Total 4 marks)

Above points can be shown in diagrams.

- 4 (a) character affected/influenced/defined/determined/controlled by two or more genes

(1)

- (b) human skin colour can vary from pale to very dark/amount of melanin varies; skin colour/melanin controlled by (alleles from) at least three/several genes; no alleles are dominant/alleles are co-dominant/incomplete dominance; many different possible combinations of alleles; skin colour controlled by cumulative effect/combination of genes/alleles

(2)

(Total 3 marks)

Award the above marking points for any other valid example.

[Note: at the time this question was written, the programme guide had human skin colour as the official example of a polygenic trait. In the current programme, human height would be a more appropriate example. Hence, marks would be awarded for only some of the things in this answer, such as the fact that height can vary, it is caused by several genes, many different possible combinations

of alleles, it results from a cumulative effect of genes or alleles. Since the mark scheme does allow for other valid examples, full credit would be given for skin colour, too.]

- 5 for two alleles of a given genetic characteristic, three possible genotypes exist; (accept examples of genotypes); predicts frequencies of dominant and recessive alleles of a given gene; homozygous for each allele and heterozygous; frequency of dominant allele = p , recessive/albino allele = q ; total frequency of both alleles = 1 or $p + q = 1$; random mating, probability of receiving two dominant alleles is $p \times p$ or p^2 ; probability of receiving two recessive alleles is $q \times q$ or q^2 expected frequency of heterozygous genotype is $2pq$; $p^2 + 2pq + q^2 = 1$; assumes no mutations/large population/random mating/no selective pressure/no immigration nor emigration; explains why recessive alleles do not disappear over several generations; $q^2 = 1/20\ 000$ or $q = 0.007$ (frequency of recessive); $p = 1 - 0.007$ or 0.993; frequency of dominant $p^2 = 0.986$ or 98.6%; frequency of heterozygotes $2pq = 0.014$ or 1.4%

Accept values with more significant figures.

(Total 5 marks)

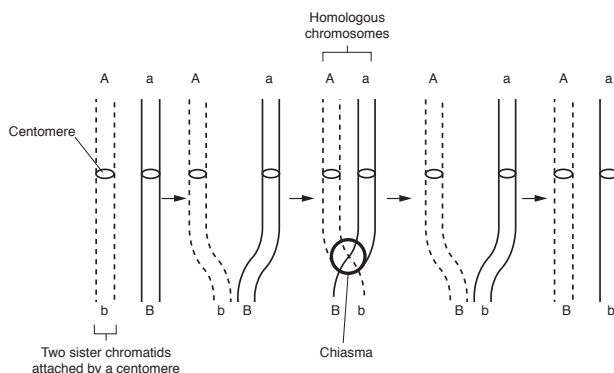
- 6 gradualism is the slow change from one form to another/stable conditions lead to low levels of natural selection making it a long, gradual process; punctuated equilibrium implies long periods without much change and short periods of fast changes/mass extinction promotes rapid change/new species

(Total 2 marks)

Challenge yourself

- 1 The diagram below shows the formation of a chiasma in five steps. Notice how it is important to show a difference between the two homologous chromosomes (solid versus dotted lines). Be sure to label the sister chromatids, centromere, homologous chromosomes and

where the chiasma forms. Notice how the original dotted chromatids all had A + b whereas the solid chromosomes had B + a. Once crossing over has happened, a new combination appears on a dotted chromatid: A + B, and a new combination appears on a solid chromatid: a + b.



- 2 Set up a 4 x 4 Punnett grid with one parent's combination of alleles on the left column and the other parent's combination of alleles on the top row. When the boxes showing the offspring are filled in by combining two alleles from each parent, you will see that all the offspring are AaBb (heterozygous for both traits).

	ab	ab	ab	ab
AB	AaBb	AaBb	AaBb	AaBb
AB	AaBb	AaBb	AaBb	AaBb
AB	AaBb	AaBb	AaBb	AaBb
AB	AaBb	AaBb	AaBb	AaBb

3

	Round yellow	Round green	Wrinkled yellow	Wrinkled green	Total
Observed (O)	315	108	101	32	556
Expected (E)	313	104	104	35	
Difference squared (O - E) ²	4	9	16	9	
$\frac{(O - E)^2}{E}$	0.0128	0.0865	0.1538	0.2571	0.5103

Degrees of freedom = 3 (4 possible classes of data - 1). The value on the critical values table for d.f. = 3 and $p = 0.05$ is 7.815. As 0.5103 is less than 7.815, we can accept the null hypothesis that there is no statistically significant difference between the expected and the observed results. There is a good fit between the expected and observed results.

4

	Purple long	Purple round	Red long	Red round	Total
Observed (O)	284	21	21	55	381
Expected (E)	214	71	71	25	
Difference squared (O - E) ²	70	-50	-50	30	
$\frac{(O - E)^2}{E}$	22.9	35.2	35.2	36.0	129.3

Degrees of freedom = 3 (4 possible classes of data - 1 = 3). The value on the critical values table for d.f. = 3 and $p = 0.05$ is 7.815. As 129 is greater than 7.815, we can reject the null hypothesis. As a result, there is a statistically significant difference between the expected and the observed results. The reason for this deviation from the expected results is that there is another phenomenon acting on the assortment of the genes: they are linked (on the same chromosome) and as a result, do not show the 9:3:3:1 expected ratio.

The offspring that are recombinants are purple + round and red + long.

- 5 (a) Disruptive.

(b) Stabilizing.

(c) Directional.

(d) Disruptive.

(e) Directional.

- 6 (a) In Lagos, Nigeria, the frequency of D is 0.83 and the frequency of d is 0.17. In Abha, Saudi Arabia, the frequency of D is 0.73 and the frequency of d is 0.27.

- (b) For the French Basques the frequency for d (0.51) is three times greater than the frequency in Lagos and nearly twice the frequency in Abha.

Answers

Chapter 11

Answers are not provided for questions that require individual research or practice.

Exercises

- 1 Memory cells are the basis of true immunity. Memory cells are not produced until a primary immune response has occurred either by first exposure to a pathogen or by vaccination. It is memory cells that respond to a second infection so quickly that symptoms of the pathogen do not have enough time to develop.
- 2 Hybridoma cells are cells that are a fusion of a B (plasma) cell and a cancerous (myeloma) cell. Because they are partially a B cell, they are capable of producing and secreting a specific antibody type. In addition, they are partially a myeloma cancer cell and thus can live and undergo mitosis for a very long time.
- 3 Smallpox is a virus that needs a human host. Once enough people were vaccinated to prevent further spread of the disease, the smallpox virus had nowhere to exist and thus no one alive carried the virus for further disease transmission.
- 4 Blood plasma does not have any blood cells. Blood type matching is based on matching the A, B, and Rh proteins on the red blood cells. Receiving a fluid (plasma) with no cells eliminates the need to match.
- 5 To give support to the body of the animal, provide anchorage for muscles, and act as levers.
- 6 Every movement of a bone or exoskeleton segment requires there be an opposite movement when needed. A single muscle can only do one thing and that is contract to cause a single movement. Thus each direction of movement requires its own muscle.
- 7 The first message to contract a muscle comes from the motor neurone's action potential and is in the form of a neurotransmitter and Na^+ ions. The movement of sodium ions then stimulates the movement of calcium ions.
- 8 (a) The biceps muscle.
(b) Tendons.
(c) The ends of the bones lined with cartilage and synovial fluid.
(d) The triceps muscle.
- 9 glomerulus (capillary or fenestrated slit); basement membrane; tubule membrane (e.g. proximal convoluted tubule); peritubular capillary
- 10 There are two possible reasons: some molecules are too large to become a part of the filtrate (e.g. proteins) and some are filtered but are completely reabsorbed (e.g. glucose).
- 11 Very little to no ADH would be secreted as this person would not need to reabsorb water from the collecting duct.
- 12 ADH would be secreted as this person could not afford to lose much water in his or her urine.
- 13 Urea is a nitrogenous waste product that is only toxic when allowed to reach relatively high concentrations in the bloodstream.
- 14 Even though these two classifications are more appropriate for aquatic and marine animals, justification can be given for humans being osmoregulators. This is because humans are constantly adjusting the level of water in their tissues by using the mechanism of ADH/collecting duct reabsorption.
- 15 Glucose is reabsorbed back into the bloodstream from the renal tubule by active transport. Active transport has a maximum rate and capacity for reabsorbing glucose. If the level of glucose in the renal tubule is higher than that rate can keep up with, the remaining glucose will be found in the urine.
- 16 Spermatozoa are very small and have only a few necessary organelles. They have an acrosome at

their anterior end that contains enzymes needed for fertilization, and they have a flagellum for swimming. The nucleus is haploid in order to be merged with the haploid nucleus of the ovum.

- 17 An ovum is a very large cell. The large volume is primarily for storing nutrients that will be necessary for the development of an embryo. A wide variety of organelles are present. The nucleus is haploid in order to be merged with haploid nucleus of the spermatozoon. Cortical granules are present to provide protection from polyspermy.
- 18 Insulin's action is designed to be a part of a negative feedback mechanism. The idea is to keep blood sugar within a normal homeostatic range. Insulin's role in this is to open facilitated diffusion channels in plasma membranes of body cells so that glucose can enter the cell. Thus blood sugar is decreased. Other actions will occur in order to increase blood sugar when necessary. For childbirth there is no normal homeostatic range. There is a culminating endpoint and that is birth. Oxytocin levels continue to increase during childbirth until that end point is reached. This type of feedback is called positive feedback.
- 19 External fertilization is not nearly as efficient as internal fertilization (a much lower percentage of eggs become fertilized). In order to make up for this, females must use a great deal of metabolic energy and resources in order to produce a very large number of eggs. In addition, there are very few examples of species that use external fertilization and show a high degree of parental care. Survival of fertilized eggs is thus relatively low.
- 20 The placenta is a structure that exchanges nutrients and waste products in molecular forms between mother and foetus, but there is no exchange of blood. Because the blood types are not mixed, the antigens on the erythrocytes that could cause an immune response are kept separate.

Practice questions

- 1 vaccine injected into body/ingested; containing killed/weakened pathogen/fragments of pathogen/toxins; macrophages ingest antigen/antigen presenting cells ingest antigen; T helper cells bind to macrophages; T helper cells stimulated/activated

antigen binds to B cells; activated T helper cells then bind to B cells; activation of B cells; which divide/undergo mitosis to form clones of (plasma) cells

B cells/plasma cells produce antibodies; memory cells produced; second/booster shot sometimes given; stimulates memory cells; more antibodies and faster response/graph to show this; antibodies are specific to antigen

(Total 8 marks)

- 2 (a) Award [1] for each structure accurately drawn and correctly labelled.

haploid nucleus; (two) centrioles; cytoplasm (must show large volume relative to nucleus – suggest four to one ratio of diameter at a minimum); (first) polar cell/polar body (needs to be drawn on the outside of the cell); plasma membrane; follicle cells/corona radiata; cortical granules (need to be drawn in vicinity of plasma membrane); zona pellucida (4 max)

(b) Award [1] for each of the following pairs up to [6 max]. Answers do not have to be in the form of a chart.

Mitosis	Meiosis
one cell division	two divisions/reduction division
chromosome number does not change (<i>do not award mark for diploid cells produced as mitosis can occur in haploid cells</i>)	converts diploid to haploid cells
products genetically identical	products genetically diverse

separation of sister chromatids in anaphase	separation of homologous chromosomes in anaphase I and sister chromatids in anaphase II
no crossing over	crossing over in prophase I
no formation of tetrads/no synapsis	formation of tetrads/synapsis
produce cells for growth/tissue repairs/asexual reproduction	produce sexual cells/gametes for sexual reproduction
two cells produced	four cells produced
daughter cells with both copies of chromosomes/random assortment does not occur;	random assortment of maternal/paternal chromosomes (provides genetic diversity)
replication of DNA in interphase	replication in interphase I
four phases: prophase, metaphase, anaphase, telophase	same four phases twice

(6 max)

- (c) crossing over (in prophase I); new combinations/recombination/exchange of alleles; non-disjunction/chromosomal mutation can occur creating new varieties; genetic mutations can occur creating new varieties; random alignment of homologous chromosomes at metaphase I/independent assortment; variety of chromosomes set $2^n/2^{23}$ (in humans); random mating in population creates new genetic combinations; random fertilization of one sperm with one egg; variations allow for better chances for survival/better adaptation; more likely to survive to reproductive age; variation allows a population to survive environmental change (8 max)

(Total 18 marks)

- 3 muscles/fibres/myofibrils contain (repeating) units called sarcomeres; muscle/sarcomeres contain actin filaments and myosin filaments; actin fibres are thin *and* myosin fibres are thick; arriving action potential causes release of Ca^{2+} ; from sarcoplasmic/endoplasmic reticulum; Ca^{2+} binds

to troponin; causing troponin and tropomyosin to move (on actin); exposing binding sites on actin/ or myosin; ATP binds to myosin heads releasing them / breaking cross bridges; ATP hydrolysed/split into $\text{ADP} + \text{P}_i$; ATP/energy causes myosin heads to change shape/swivel/ become cocked; myosin heads bind/form cross-bridges to (exposed) actin binding sites; myosin heads swivel / move actin (releasing $\text{ADP} + \text{P}_i$); myosin filaments move actin filaments towards centre of sarcomere; sliding of filaments / actin and myosin shortens the sarcomere (9 max)

(Plus up to [2] for quality)

- 4 labelled diagram showing, biceps, humerus, radius, and ulna; cartilage reduces friction; synovial fluid lubricates the joint; synovial membrane secretes synovial fluid; capsule/ capsular ligament seals the joint; ligaments prevent dislocation/restrict the range of movement/attach bones to one another; motor neurones stimulate muscles to contract; bones provide a firm anchorage for muscles; bones act as levers/change the torque/size/direction of forces; tendons attach muscle to bone; biceps and triceps are antagonistic; biceps is the flexor / bends the elbow joint **and** triceps is the extensor/straightens the elbow joint; biceps is attached to the radius and triceps is attached to the ulna (8 max)

Accept any of the above points if clearly drawn and correctly labelled in a diagram. (Plus up to [2] for quality)

- 5 A (Total 1 mark)

- 6 C (Total 1 mark)

- 7 Award [4 max] for:

produced in hypothalamus; via neurosecretory cells; passes from hypothalamus to (posterior) pituitary; attached to carrier protein; (stored) in posterior pituitary; released under stimulus by osmoreceptors in hypothalamus; osmoreceptors stimulated by high blood plasma concentration/ reduced blood pressure; increases water reabsorption (in kidneys)

Award [2 max] for:

site of action is collecting duct; promotes constriction of blood vessels; increases blood pressure; there is a negative feedback control of ADH/vasopressin secretion

(Total 6 marks)

Challenge yourself

- 1 (a) Yes. Someone who is AB⁺ has all three proteins that could be considered an antigen. Therefore they can receive blood of any type, including O⁺.
(b) No. A person with blood type O is giving neither the A or B protein, but because the donor is Rh⁺ they would be giving the recipient the Rh protein that is not part of their own blood type. This transfusion should not be allowed.
(c) Yes. Someone who is O⁻ is considered to be the universal donor because they have none of the three erythrocyte proteins that are antigens to those who do not have them already. O⁺ people can receive blood from other O⁺ people or O⁻ people.
- 2 Compare your sketch to Figure 11.11. Your sketch should have all of the major components as shown.
- 3 (a) The great white shark is a type of fish (a cartilaginous fish) and thus, like all fish, produces ammonia.
(b) Even though a walrus is a marine mammal, it is still a mammal with mammalian evolutionary ancestors. Thus urea is its primary nitrogenous waste.
(c) A penguin is a flightless bird, but is still a bird. Therefore penguins use the same type of self-contained eggs that all other birds use. Therefore, a penguin uses uric acid as its primary nitrogenous waste.
(d) All marine sea turtles are reptiles and use the same type of self-contained eggs as birds. Therefore, marine sea turtles use uric acid as their primary nitrogenous waste.
- 4 (a) Diploid (this cell has not yet begun meiosis).
(b) Haploid (this cell has completed meiosis I, thus the homologous pairs have split).
(c) Diploid (this cell has not yet begun meiosis).
(d) Diploid (this cell has replicated its DNA but has not yet split any chromosomes).
(e) Haploid (this cell has completed meiosis I, thus the homologous pairs have split).
(f) Diploid (this cell is the union of both haploid nuclei, thus the diploid number has been restored).

Answers

Chapter 12

Answers are not provided for questions that require individual research or practice.

Exercises

- 1
 - Closure of the neural tube does not take place equally.
 - Towards the tail end (caudally) the tube may not finish closing during development.
 - Failure of the neural tube to close in the caudal region in the human embryo at day 27 results in spina bifida.
- 2
 - The neurones of the central nervous system in the developing vertebrate embryo have their source in the neural tube.
 - Neuroblasts are immature neurones that are the precursor cells of neurones.
 - The process of differentiation from neuroblast to neurone is called neurogenesis.
 - As soon as the neural tube begins to transform into specific brain parts, two major families of cells begin to differentiate.
 - The two types of cells are neurones and glial cells.
 - Neurones carry messages while glial cells do not carry messages.
 - 90% of brain cells are glial (meaning glue) and have many functions. One important function is physical and nutritional support of the neurone.
 - Most of the new neurones in the human cortex are formed between the fifth week and the fifth month of development.
 - Glial cells provide a scaffolding network along which the immature neurones migrate.
 - Along this scaffolding of the glial cells, immature nerve cells can migrate to their resting place, finally mature, and send out their axons and dendrites.
- 3 Neural pruning is the elimination of axons that are not being used. The purpose seems to be removal of the simpler connections of

childhood and replacement by more complex wiring present in adulthood. Synapses that are rarely used are eliminated and those with strong connections are maintained. Removal of unneeded connections leads to improvement in brain efficiency.

- 4 The brain exhibits two types of plasticity, functional and structural. Functional plasticity is the ability of the brain to move functions from a damaged area to an undamaged area, for example when stroke patients learn how to use their arms and legs again. Structural plasticity is the fact that the brain can actually change its physical structure as a result of learning, for example the hippocampus of London taxi drivers is larger than other people's because of their learnt knowledge of the London streets.

5

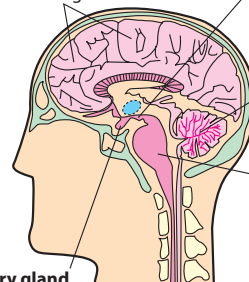
Cerebral hemispheres are associated with intelligence, personality, sensory impulses, motor function, organization and problem solving.

Hypothalamus controls the pituitary gland, which secretes hormones.

Cerebellum is associated with the regulation and coordination of movement and balance.

Medulla oblongata maintains vital body functions such as breathing and heart rate.

Pituitary gland secretes hormones.



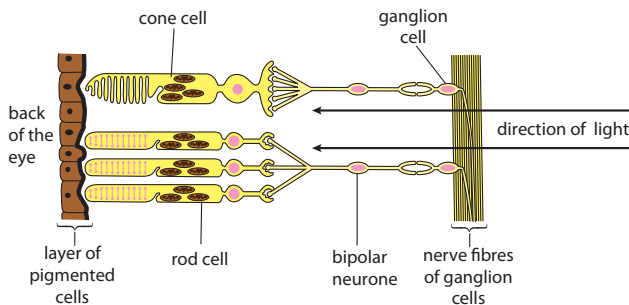
Annotations:

- Cerebral hemispheres act as the integrating centre for high complex functions such as learning, memory, and emotions.
- The hypothalamus maintains homeostasis, coordinating the nervous and the endocrine systems, secreting hormones of the posterior pituitary, and releasing factors regulating the anterior pituitary.

- The cerebellum is often called 'the little brain' because it has two hemispheres and a highly folded surface. It coordinates unconscious functions, such as movement and balance.
 - The medulla oblongata controls automatic and homeostatic activities, such as swallowing, digestion, vomiting, breathing, and heart activity.
 - The pituitary gland has two lobes. The posterior lobe stores and releases hormones produced by the hypothalamus and the anterior lobe. It also produces and secretes hormones regulating many body functions.
- 6** fMRI uses radio waves and a strong magnetic field, not X-rays. This instrument enables scientists to see the blood flow in the brain as it is occurring. Researchers make movies of what is going on in the brain as the subject performs tasks or is exposed to various stimuli. This method can produce a new image every second. It can determine with some precision when regions of the brain become active and how long they remain active. This means it is possible to determine whether brain activity occurs in the same region or different regions all at the same time as the patient responds to experimental conditions.
- 7** Broca's area is one of the main areas of the cortex responsible for producing language. Nucleus accumbens is associated with the reward circuit in the brain. It responds chiefly to two neurotransmitters, dopamine and serotonin. Dopamine promotes desire; serotonin inhibits desire.
- The visual cortex is a part of the brain that receives information from the cells of the retina in the eye. The visual cortex is one of many brain centres that cooperate to produce our vision.
- 8** Greater cognitive ability and more advanced behaviour are associated with an increased size of the cerebral cortex. When we compare human brains with those of other animals, the biggest discrepancy appears in the size of surface area of the cerebral hemispheres. In a mouse, for example, the surface of the cerebral cortex is smooth, while in a dog it is very convoluted. When we study monkeys and apes, even more folds are found in their cortex. In order for the brain to fit into a skull that is in proportion to the rest of our body, the brain has to fold in on itself. The increased surface area is needed for more complex behaviours, but it still has to fit into a skull with limited space. One way to have more working surface is by folding. If you wrinkle up a sheet of paper, it has the same surface area but will take up less space. As species evolved to have more complex behaviours, they had to develop more working area in their brain. The more folding, the more surface area is available. In this way the larger surface area of the cerebral cortex can be contained in a limited space. An interesting fact is that a 6-month old foetus has a completely smooth cerebral cortex. By birth it has become the walnut-like structure we would expect to see. The folding during development of the human embryo takes place over the last 3 months of development.
- 9**
- Neurones have a high need for energy because they are always in a state of high metabolic activity.
 - Metabolism consists of all the chemical activities performed by a cell.
 - The neurone performs many tasks that are similar to other cells, such as repairing or rebuilding their structural components.
 - The chemical signals that are responsible for communication between neurones consumes half of the energy used by the brain.
 - This is why a brain cell needs double the energy of any other cell in your body.
 - Glucose is the primary energy source fuelling the metabolism of neurones in the human brain.
 - Neurones cannot store glucose, so the blood must deliver a constant supply.
 - Blood sugar (glucose) is supplied by the food that you eat. High-quality carbohydrates such

as fruits, vegetables, legumes, grains, and dairy are the best source of glucose.

10



Annotations:

- Rod cells are photoreceptor cells that are very sensitive to light. They receive the stimulus of light, even very dim light, and synapse with a bipolar neurone.
- Cone cells are photoreceptor cells that are activated by bright light. They receive the stimulus of bright light and synapse with a bipolar neurone.
- Bipolar neurones are cells in the retina that carry impulses from a rod or a cone cell to a ganglion cell of the optic nerve. They are called bipolar because they each have two processes extending from the cell body.
- Ganglion cells synapse with the bipolar neurones and send the impulses to the brain via the optic nerve.

11

Rods	Cones
These cells are more sensitive to light and function well in dim light	These cells are less sensitive to light and function well in bright light
Only one type of rod is found in the retina. It can absorb all wavelengths of visible light	Three types of cone are found in the retina. One type is sensitive to red light, one type to blue light, and one type to green light
The impulses from a group of rod cells pass to a single nerve fibre in the optic nerve	The impulse from a single cone cell passes to a single nerve fibre in the optic nerve

12 Normal vision uses the three classes of cones, red, green, and blue, and is called trichromatic vision. Some individuals are dichromatic and have red–green colour vision defects. As red–green defects are inherited as a sex-linked trait, the mother gives it to her sons. It is very rare for females to have this trait. Dichromatic vision is a variant of trichromatic vision. It can be caused by the presence of blue and green cones with no functional red cones (red-blindness) or by having blue and red cones and missing green (green-blinded). Dichromats see the world differently depending on the variation they have inherited.

13 Cochlear implants are a product of medical technology, which has improved the lives of people with severe to profound hearing loss when a hearing aid is not a solution. This device converts sound into electrical signals, which are sent directly to the brain. A cochlear implants works in the following manner.

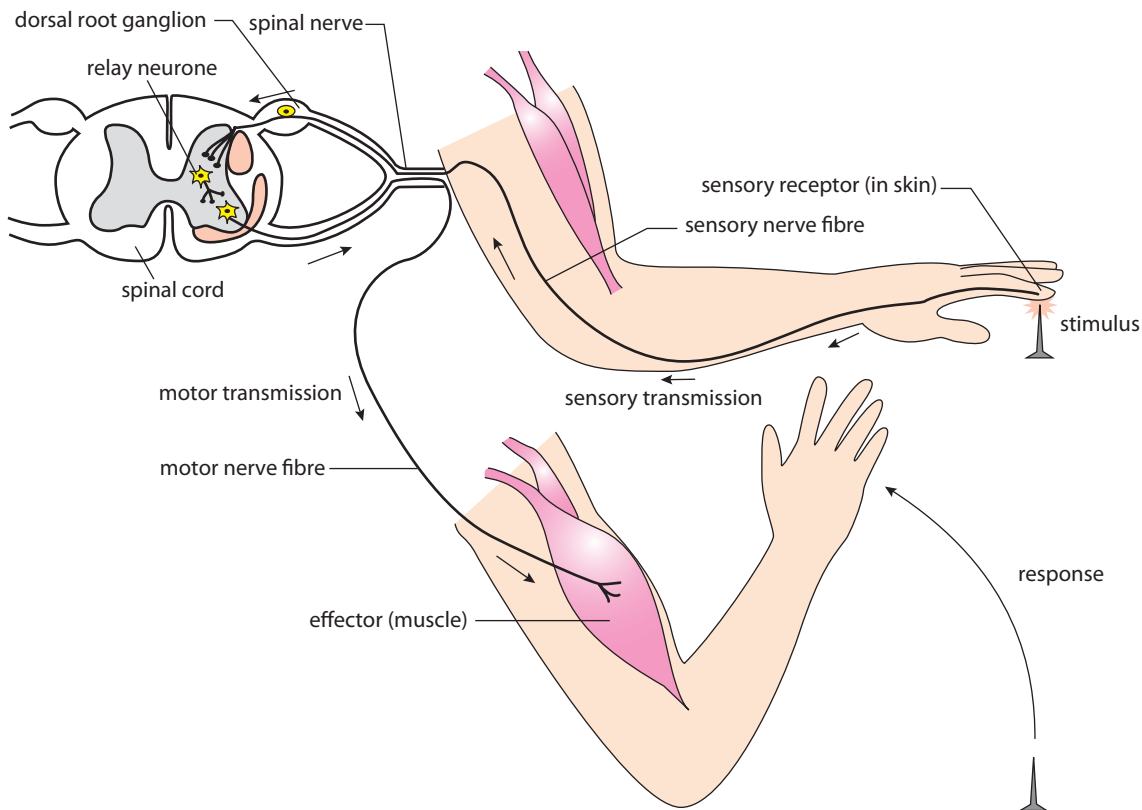
- An external processor is worn behind the ear or magnetically attached to the hair.
- The microphone in the external processor picks up the sound signal.
- The external processor digitizes the sound and transfers the electrical signal to the implant, which has been surgically placed in the cochlea.
- The implant acts like a miniature computer, deciphering the digitized sound and transferring it into electrical signals.
- The auditory nerve picks up the electrical signals and sends a message to the brain.
- The brain interprets the signals as sound.

14 Sound waves are successive vibrations of air molecules caught by the outer ear. When they travel down the auditory canal, they cause the eardrum (tympanic membrane) to move back and forth slightly.

- The bones of the middle ear (malleus, incus, and stapes) receive vibrations from the tympanic membrane and multiply them approximately 20 times.

- The stapes strikes the oval window causing it to vibrate.
- This vibration is passed to the fluid in the cochlea.
- The fluid in the cochlea causes special cells, called hair cells, to vibrate.
- The hair cells, which are mechanoreceptors, release a chemical neurotransmitter across a synapse to the sensory neurone of the auditory nerve.
- Vibrations are transformed into nerve impulses.
- The chemical message stimulates the sensory neurone.
- Impulses caused by sound perception are transmitted to the brain by the auditory nerve
- The round window releases pressure so fluid in the cochlea can vibrate.

15



- 16
- After training, it is possible to elicit a reflex response (here an eye blink) with a new and neutral stimulus.
 - First, the neutral stimulus (e.g. a musical note) is introduced. The subject probably does not blink. Next the subject is given a period of training: the musical note is sounded immediately before a hand is waved in front of the subject's eye. Eventually the subject responds with an eye blink to just the musical note.
 - After this has occurred, the musical note is called the conditioned stimulus and the eye blink in response to the musical note is called the conditioned response.
 - The subject is now responding to a musical note in a new way.

17 This table compares innate and learned behaviour.

Innate behaviour	Learned behaviour
Develops independently of the environmental context	Dependent on the environmental context of the animal for development
Controlled by genes	Not controlled by genes
Inherited from parents	Not inherited from parents
Developed by natural selection	Develops as a result of experience
Increases chance of survival and reproduction	May or may not increase chance of survival and reproduction

18 Encoding

During encoding the brain processes information that it receives from the senses so that it can be remembered. The following are some types of encoding done by the brain.

- Visual encoding: converting information into mental pictures.
- Elaborative encoding: relating new information to old knowledge already stored in memory.
- Acoustic encoding: encoding of sound, such as spoken language.
- Sensation encoding: encoding of sensations, such as touch, odours, and tastes.
- Semantic encoding: remembering sensory input in a context. For example, using a mnemonic device such as ROYGBIV as a strategy to remember the colours of the light spectrum in order (red, orange, yellow, green, blue, indigo, and violet).

Storage

The ability to store information allows us to maintain the knowledge gained for a certain period of time. Storage occurs at the level of the neurone. Neurones synapse with each other using molecular signals. With increased numbers of transmitted signals, the strength of the synaptic connection also increases. This is

why practice makes perfect! If you sing a song over and over again, repeating the signals between the neurones make for better memory.

Accessing

The two main methods of accessing memories are recognition and recall.

- Recognition is the association of a physical object or event with something already experienced. It involves comparing present information with memory. If you see a face in the crowd and remember who that is, that is recognition.
- Recall involves remembering a fact, object, or event that is not currently present. Actively reconstructing the memory requires the activation of all of the neurones involved in the memory. This is much more complicated than recognition. Recognition simply requires a decision about whether or not something has been encountered before.

19 A postsynaptic neurone is on the receiving end of many excitatory and inhibitory stimuli. The postsynaptic neurone sums up the signals. If the sum of the signals is inhibitory, then the impulse is not carried forward. If the sum of the signals is excitatory, then the impulse is carried forward. This is the interaction that takes place between the activities of the excitatory and inhibitory neurones at the synapses. The summation of the messages is the way that decisions are made by the central nervous system.

- 20**
- Slow-acting neurotransmitters can regulate the efficiency of neurotransmitter release from the presynaptic terminal (the sender).
 - Slow-acting neurotransmitters can regulate the efficiency of the postsynaptic receptor (the receiver).

21 Learning

The action of slow-acting neurotransmitters on neurones is what allows the brain to have the function

of learning and eventually memory. Specific molecular activities have been identified in certain nerve cells.

- A slow-acting NT such as serotonin acts on a presynaptic neurone.
- This causes an influx of Ca^{2+} into the presynaptic neurone.
- The increase in Ca^{2+} causes the production of cyclic (c)AMP, which is a second messenger.
- cAMP activates another molecule, PKA (protein kinase).
- PKA enhances the release of the neurotransmitter from the presynaptic neurone into the synapse.
- The result is short-term learning.

The biochemical cascade mentioned above increases neurotransmitter in the synapse and strengthens it. The result is short-term memory. The process uses cAMP, which is a second messenger.

Memory

- The long-term process of memory requires the synthesis of proteins. The synthesis of proteins necessitates the activation of genes in the nucleus of the neurone. The proteins change the form and function of the synapse. This results in memory.

22 If the message received by the sensory receptor arrives at the central nervous system (CNS), you will feel the pain. Novocain is a local anaesthetic that can block nerve transmission to the pain centres. When positive sodium ions are diffusing into the postsynaptic neurone, then the message is being carried along the nerve. Local anaesthetics like Novocain block the gated ion channel through which Na^+ is moving. No pain signals can then be carried through to the CNS. Local anaesthetics produce drug-induced insensitivity to localized pain. General anaesthetics are usually volatile and inhaled and thus affect the whole body. The result is a generalized insensitivity to pain. Normal heart

rate and blood pressure are maintained but there is a reversible loss of consciousness. General anaesthetics are usually used in surgery. During the surgery you lose consciousness completely and have no awareness of pain.

23 Scientists studying animal behaviour have observed some populations of animals that have changed the frequency of their behaviour. For example, birds may migrate earlier, salmon may mature quicker, courtship patterns in birds may become more extreme. These behavioural changes may be so extreme that a new species is formed, as might eventually occur with European blackcaps. Through careful observations, ethologists have collected data to show that natural selection, which increases the chances of survival and reproduction, has acted on genetically caused behaviours. This has made those genetically caused behaviours more prevalent in the population.

24 In the beginning of the 20th century, milk was delivered to the doorsteps of British residents. At that time milk had a layer of cream, which settled on the top. Use of the mechanism (homogenation) for mixing the cream and milk so that it does not separate was not common then. At that time, people liked to skim the cream off the top for their coffee, etc. The problem was that the blue tits also liked to suck up the cream off the top of the bottle, as it sat on the doorstep! Another bird that did this was the robin.

How does learning enter into this picture? When the dairy industry decided to cover the bottle with an aluminium seal, it was observed that only the blue tits had learned to remove the aluminium seal to get to the cream, while the robins had not. A few robins could remove the aluminium seal, but it did not become a prevalent mode of action in robin populations. However, it did become almost universal in blue tits. In fact the behaviour spread all over the country. Scientists became interested in how this learned behaviour was spread.

Data were collected that demonstrated that blue tits normally peel bark off trees to look for insects. This is similar to the technique they use to peel the tops off the milk bottle. How about the comparison with robins? It seems that robins are solitary birds while blue tits are flock birds. Can part of the answer be that the learning was propagated socially in the flock? Researchers in Canada and Austria set up experiments to test the learning of blue tits and to try to determine whether the learning was social. All experiments supported the view that the bottle opening was a combination of innovation by some blue tits and learning that was spread by social communication.

Practice questions

1 (a) 24% ($\pm 2\%$) (*units required*) (1)

(b) 8 (± 0.5):42 (± 0.5) or 16 (± 1):84 (± 1) or 1:5.25 (± 0.25) (1)

Accept the following alternatives 11:44 (± 0.5) or 1:4 (± 0.25).

(c) small females have more saturated lipids than large females/large females have more unsaturated lipids than small females; large females have a peak (unsaturated lipids) at 26 minutes while small females do not have a peak present; large females have two peaks (unsaturated and saturated) at 23 minutes while small females do not; large peaks for small females emerge sooner than for large females (2 max)

(d) (i) apply lipids to substrate/skin of snake; then introduce male snake and record preference; use of control (2 max)

(ii) larger females have larger/more offspring; better survival of offspring (1)

(Total 7 marks)

2 (a) behaviour that occurs in all members of a species despite variation in the environment/

inherited behaviour/stereotyped behaviour/
not learnt/instinctive (1)

(b) shine light in eye to see if pupil constricts; pupil reflex is a cranial reflex/ANS reflex/controlled by the brainstem; if pupil reflex is lost, patient is most likely brain dead; some drugs (barbiturates)/nerve damage may interfere with pupil reflex (2 max)

(Total 3 marks)

3 (a) psychoactive drugs affect the mind/brain and mood; change/increase synaptic transmission; (drugs) can block/similar in structure/inhibit breakdown of neurotransmitter
Award (2 max) per example, e.g. cocaine/nicotine/amphetamines. Accept only effects on the synapse and behavioural effects
cocaine/crack: stimulates synaptic transmission of adrenergic synapses; increases energy/alertness/euphoria
nicotine: stimulates synaptic transmission of cholinergic synapses; has a calming effect
amphetamines/ecstasy: stimulates synaptic transmission of adrenergic synapses; similar effects to cocaine; longer lasting effect/2 to 4 hours (6 max)

(b) both are part of the autonomic nervous system; antagonistic to each other/counteracts; the sympathetic prepares the body for action while the parasympathetic returns the body function to normal; example of any effect comparing the action of the sympathetic and parasympathetic systems in a tissue or organ (e.g. heart: sympathetic increases output and parasympathetic returns it back to normal); a second example (4 max)

(Total 10 marks)

4 (a) (i) 25 (± 3)% (1)

(ii) 6.4 (± 0.6): 1/32.5 (1)

(b) resting and patrolling (1)

- (c) first activity is cell cleaning; followed by building comb and capping comb; finally the bee is foraging; eating pollen/tending brood/ play fights occur at lower levels for most of the time; dance-following occurs towards the end of the 24 days (3 max)
- (d) patrolling is altruistic/improves survival of hive/shows division of labour/helps others (1)
- (Total 7 marks)
- 5 (unconditioned) stimulus of food/sight of food accompanied by bell ringing; salivation is the (unconditioned) response; (conditioned) stimulus of bell ringing before/without unconditioned stimulus/sight of food; salivation became the conditioned response (to the bell ringing)
- (Total 3 marks)
- 6 (a) crab A (1)
- (b) $20(2) \text{ cm s}^{-1}/13(0.5) \text{ cm s}^{-1}/4(2) \text{ cm s}^{-1}$ (units required) (1)
- (c) the fastest water velocity resulted in the most direct approach; the lowest water velocity resulted in the lowest hunting speed of the crabs; the fastest water velocity resulted in the least lateral movement; slowest crab has the most lateral movement; intermediate water velocity resulted in the fastest movement between any two points (2 max)
- (d) nature of the river bed may influence movement; water temperature may influence the spread of the dye/movement of crab; depth of the creek may influence the spread of the dye; time of the day may influence the activity of the crabs; presence of other (unseen) predators/presence of camera will influence the behaviour of the crabs; age of crab will influence speed; size/sex of crab will influence speed; food availability; width of plume; concentration gradient; dye might effect the behavior of the crab (2 max)
- (Total 6 marks)
- 7 (a) I: aqueous humour; II: fovea/yellow spot/macula lutea (2)
- (b) slowing of heart rate; lowers blood pressure; constriction of the pupil; saliva production; constriction of ciliary muscle; constriction of bronchioles; increases gut movement; increases secretion of gastric juices/pancreatic juices/tears; relaxes gut sphincters; erection of penis; constriction of bladder wall; relaxation of bladder sphincter; gall bladder constriction (1 max)
- (Total 3 marks)
- 8 (a) 5.2 to 5.3 mm (units required) (1)
- (b) 15 (1)
- (c) as head width increases, mating success increases; highest mating success at head width 5.6–5.7 mm; above 5.6–5.7 mm head width, mating success drops (2 max)
- (d) smaller so not so good at fighting; lighter so can hover easily (1 max)
- (Total 5 marks)
- 9 (a) $\frac{52-20}{20} \times 100 = 160\%$ (units required) (1)
- (b) bees with previous exposure/experimental group fly around the source more than the control group; bees with previous exposure/experimental group fly towards the source more than the control group; bees with previous exposure/experimental group circle more than the control group; in bees with previous exposure, orientated flight is greater than circling
Accept vice versa statements. (2 max)
- (c) the bees associate the odour with food, and this is learned/conditioning behaviour (1)
Do not accept taxis or simply learned behaviour or conditioning.
- (d) previous exposure leads bees to fly to food source more directly; giving them an advantage in finding food; increasing their chance of survival; and passing their genes to the next generation; less energy

expended finding food; more direct flight/
less flight time reduces chance of predation
(3 max)
(Total 7 marks)

- 10 (a) A: cone
B: rod
C: bipolar cell
D: ganglion cell

Two structures required for (1 marks). All four
structures required for (2 marks). (2)

- (b) arrow drawn from bottom of diagram
pointing upwards (1)

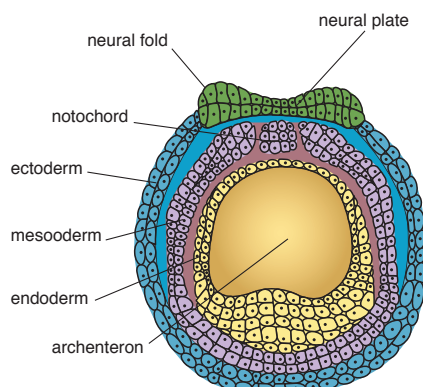
- (c) A direct comparison must be made.
rod cells more effective in low light/night than
cone cells; *Accept converse*
rod cells detect a broad range of
wavelengths/colours whereas cone cells are
sensitive to a specific wavelength/specific
colours; groups of rod cells pass impulses
to a single nerve fibre whereas a single
cone cell passes impulses to a single nerve
fibre/rods give less visual acuity; both are
photosensitive; rod cells more sensitive to
movement whereas cone cells give higher
visual acuity/sharpness; rod cells respond
more slowly to light whereas cone cells
respond more rapidly (3 max)
(Total 6 marks)

Archenteron	Becomes the gut
Endoderm	Forms the lining of the gut and lining of other organs
Mesoderm	Develops into the skeletal, reproductive, circulatory, excretory, and muscular systems
Ectoderm	Will become the brain and nervous system
Neural plate	Folds and closes, and becomes the neural tube
Neural fold	Edges of the neural plate will eventually fold together
Notochord	A mesodermal tissue that causes the ectoderm to develop into the neural plate

- 3 Human, dolphin, chimp, and monkey.
4 This is an energy-rich diet, which is needed to sustain the larger brain.
5 Rat, rabbit, mouse.
6 It is an energy-poor diet.
7 Having a very complex social system requires a larger brain.
8 They do not have a complex social system.
9 Octopus.
13 45–75%
14 10–65%
15 Outliers.
17 'Specific binding' indicates how many receptors are full or have been bound to serotonin. Active receptors will bind to serotonin. The higher the specific binding number, the more active receptors are present.
18 The control has the most active receptors. Evidence of this is the high specific binding number of about 0.28.
19 The binding for 0.25 is about 0.06, while the binding for day 1 is about 0.13. In less than 1 day the amount of active receptors for serotonin has doubled.

Challenge yourself

1



Embryonic tissues in *Xenopus*.

- 20** Over the 21 days, the process slowly reversed itself and the receptor density returned to normal.
- 21** By 8 hours following the last dose of MDMA, the neurones had deactivated most of their serotonin receptors. Serotonin is used up because of the SERT receptors removing serotonin from the synapse. The receptors become deactivated because of the lack of serotonin.
- 22** The control groups are saline–saline and saline–vitamin C. They are controls because neither have MDMA. Saline is simply salt solution. Vitamin C in salt water has no effect.
- 23** MDMA in saline shows increasing levels of oxidative radicals up to day 5, and between day 5 and day 8 a slight lowering of oxidative radicals can be seen. The rats that received vitamin C and MDMA do not have significantly different oxidative radicals compared with those rats that received saline only or vitamin C only.
- 24** This experiment indicates that, in rats, vitamin C can reduce the levels of oxidative radicals when these levels are high because of the use of MDMA.
- 25** The innate behaviour of lions having a synchronized oestrus cycle is beneficial to the offspring because it makes care of the cubs easier.
- When new males move in to a pride, they kill or chase out all the cubs.
 - Loss of their cubs causes all the females to move into oestrus within 2 weeks.
 - This is an innate, synchronized response to the loss of the cubs.
- Oestrus is a period of sexual receptiveness.
- All the females will then bear young at about the same time.
 - This allows the females to care for the cubs jointly.
 - Females are the main hunters.
 - They hunt in groups and care take for the cubs in groups. All the cubs are raised in a community.
 - All lionesses suckle all cubs and protect all cubs.
 - If one lioness dies, another female can raise the cub. In other words, all the females of the pride are protecting the genes they share in common.
 - If all the cubs are different ages, the great variety in size might cause younger cubs to be bullied and harmed by older cubs.
 - It is more difficult for a female to be out hunting and patrolling as if the cubs are of different ages and some are too young to be left alone.
 - Studies have shown that when birthing of the cubs occurs at the same time, it is a distinct advantage that increases the survival rate of the cubs.
 - If the cubs survive to sexual maturity, the genes they carry have a high chance of being carried on in the next generation.
- 26** Feeding on the cream in milk bottles by blue tits is learned behaviour.
- This behaviour spread through the population in a short time because of the social learning present in blue tit populations, which live in flocks.
 - Individual robins may have learned to remove the top from the milk bottle but could not learn from each other because they are more solitary and less social than blue tits.
 - Eventually the behaviour was lost in blue tits because the environmental context changed: the milk bottles with cream disappeared.
- 27** Natural selection is the process by which organisms with favourable traits survive and reproduce more successfully than organisms that do not possess those traits. Exactly which

animals survive and which do not is determined by their surroundings and the compatibility of those characteristics with those surroundings. Natural selection has acted on the genetically caused behaviour of European blackcaps.

- Blackcaps wintered in Germany and migrated to Spain to breed and raise offspring.
- About 50 years ago some blackcaps began migrating to Britain, which is a shorter trip and there are many gardens there full of bird seed for them to feed on in the winter.
- Experiments show that migratory patterns are a genetically caused behaviour. For example, raised independently of parents, offspring of Spanish blackcaps will migrate to Spain, and British offspring will migrate to Britain. Hybrids will migrate to an intermediate destination.
- Natural selection has favoured the British birds because of humans feeding them from garden feeders. Without those feeders, the British blackcaps would probably have died. The feeders provided the surroundings that enabled them to survive so that they could go back to Germany and reproduce.
- Natural selection has favoured the Spanish birds in Spain, because the original genes adapted them to this environment. The availability of fruit for food in Spain provides the surroundings that enable them to survive so that they can go back to Germany and reproduce.
- The two groups are becoming two species because they do not interbreed. Spanish birds come to Germany too late to mate with British birds, which precede them.

28 Shore crabs and how they forage for mussels is an example of how optimal prey choice can increase chances for survival.

- Shore crabs open mussels with their claws. It seems logical that the crabs would choose the largest mussels available in order to get the most food energy. However, that is not the case.

- Shore crabs choose medium-sizes mussels that they can open easily without damaging their claws.
- Because claws are very important in sexual selection and mating success, the risk of claw damage is of greater importance to foraging shore crabs than getting maximum energy from a mussel.
- This demonstrates how optimal prey choice (choice of medium mussels rather than large mussels) increases the chances for survival (less claw damage).
- It also increases the chances for reproductive success.

29 Breeding strategy is the method for increasing your chances for survival and reproduction. The two types of male coho salmon, hooknose and jack, exhibit different breeding strategies.

- Hooknose salmon are large and fierce, while jack salmon are smaller and sneaky.
- Jacks are smaller as juveniles and develop in a shallow area of the stream called a riffle. The riffle contains abundant food. This allows the jacks to grow quickly and head out to sea earlier.
- They return to spawn with females at least 1 year earlier than the hooknoses.
- Over many generations, the females can produce more offspring by mating with jacks. They can pass on the traits that lead to a shorter maturation time.
- It seems that the quiet strategy pays off. Observations show that jacks will sneak up on females while hooknoses are fighting each other.
- One might think that the more powerful and colourful hooknose is more attractive to females, but in one study 75% of jacks mated and only 58% of hooknoses mated.
- Both strategies are effective.
- Having two strategies is beneficial because it increases the genetic variation in a population.

- 30** Mate selection is important for survival and reproduction in a species. Birds of paradise have evolved on the island of New Guinea, a place with abundant food and no mammalian predators. This group of birds is one of the most prominent avian examples of sexual selection.
- Their courtship rituals are extreme.
 - Female birds of paradise are much less coloured and feathered than the males.
 - The males display both extreme colour and fancy behaviour to show off in front of the females.
 - The condition of his plumage and quality of his colours indicates to a female whether a male is healthy and will produce healthy offspring.
 - Most males have extravagant plumage and display behavioural oddities such as puffing up their bodies, fanning out their feathers, and dancing in dizzying circles.

All of these attractive features are genetically determined. These traits are passed down to male offspring and become even more prominent in the species. This is sexual selection. Females are looking for males with the most vigour and the most fitness; the courtship dance proves this vigour and fitness to the female. As it is the females who decide who to mate with, females affect how males evolve.

- 31** Altruistic behaviour can be developed by natural selection. Altruistic behaviour is one that benefits others at a cost to one's self. A donor bat gives food to a recipient bat whose chances for survival are then increased. Some recent studies have shown that female bats regurgitate blood to long-term associates on a regular basis. The regurgitation of blood to one another significantly increases their chances of survival.
- Vampire bats will die if they do not have a meal of blood for 2 days in a row.
 - Food sharing can help your close associate survive.
 - Studies have shown that only 70% of bats have a blood meal every evening.
 - Individuals who are on an equal basis share resources with each other: it becomes an advantage for both.
 - Bats are more likely to share food with others that have recently shared food with them.
 - Regurgitation of blood to close fellow bats seems to be an altruistic behaviour that has developed by natural selection.
 - The selection factor would be that those that share blood with close associates are those that survive to reproduce.
 - Thus genes controlling this behaviour are carried on in the population.

Exercises

- 1 Pathway or metabolic engineering is the practice of optimizing genetic and regulatory processes within microorganisms. The purpose of controlling the genes of a microorganism and regulating its biochemical pathways is to increase the production of a substance by the cell that is the desired product.

Photosynthesis and respiration are examples of pathways. Microorganisms have pathways they use to make a product they need. Genetic engineers can change the pathway by giving the microorganism a new gene. With a new gene there is a new product. We want this product for some reason.

- 2 (Comparison) Both terms refer to the amount of nutrients added to the fermenter, but (contrast) batch (fed-batch) is where the nutrient and substrate are added a little at a time, and continuous batch is where substrate is continuously added and an equal amount of fermented medium is continuously removed.

- 3 Comparison:
- both have cell walls
 - both have peptidoglycan
 - both have plasma membranes.

Contrast

	Gram positive	Gram negative
Cell wall structure	Simple	Complex
Amount of peptidoglycan	Large	Small
Placement of peptidoglycan	In the outer layer	Covered by the outer membrane
Outer membrane	Absent	Present with the lipopolysaccharides attached

- 4 Pathway engineering has been very successful using bacteria and yeast because:

- these organisms have a high yield compared with plants
- these organisms have a fast growth rate
- the desired product can be easily purified
- the carbon sources needed (glucose or glycerol) are simple and inexpensive.

- 5 Electroporation makes pores in the cell membrane using electrical impulses. The cell membrane of a plant cell is surrounded by a cell wall, which is made of cellulose. It gives the cell shape. The cell wall is removed to expose the protoplast. When short high-voltage electrical impulses are applied to a suspension of protoplasts, small microscopic pores are created in the cell membrane, enabling DNA to enter the cell and nucleus. In this way, transgenes can be embedded in a plant cell.

Biolistics: DNA is coated onto microparticles of gold or tungsten and fired with an explosive charge from a particle gun. The plant cells are transformed, so that new DNA of interest is added to the chromosome of the plant cell. Finally, the transformed plant cell acclimates and regenerates into a plant.

Microinjection: the DNA is injected into a protoplast with a microneedle. It is very labour intensive to use this method, as it is done one protoplast at a time. A whole plant is then grown from a protoplast.

- 6 Scientists have developed methods to engineer a plasmid called the Ti (tumour-inducing) plasmid and make it a vector for carrying genes of interest into plants. The plants express the gene making a protein that is the desired product. In the case of soybeans, the protein is an enzyme that allows the plant to use an alternative

pathway that resists the herbicide glyphosate. We call the soybeans glyphosate-tolerant soybeans. The common name for glyphosate is Roundup. Plants that contain this herbicide are called Roundup ready. Fields can be sprayed with glyphosate and weeds are killed but the soybeans are not affected.

- 7 Complex architecture: organisms in a biofilm join together in colonies, and form stable attachments to their substrate. Then the cells begin to produce EPS or extracellular polymeric substances. This protects the entire biofilm.

Quorum sensing: quorum sensing is the ability of microorganisms in a biofilm to cooperate with each other. They seem to be able to communicate with each other to make more EPS, just like bees in a hive communicate with each other.

Resistance to antimicrobials: research is being done to try to determine what makes biofilms resistant to antimicrobials. It may be because the polysaccharide matrix in which they live protects them or, because the biofilm is such a mix of organisms, many resistant strategies have been developed.

- 8 Degradation of a hydrocarbon pollutant by the action of *Marinobacter* on benzene. *Pseudomonas aeruginosa* can biodegrade crude oil. *Pseudomonas* also cleans up mercury pollution.
- 9 A trickle filter is a biofilm of aerobic bacteria attached to the surface of filter media. Waste water trickles over the filter media and the attached aerobic bacteria oxidize the organic matter in the waste. The media used currently are plastic particles with high surface areas.
- The biofilm of aerobic bacteria covers each plastic particle.
 - Oxygen is dissolved in the water of the filter bed and is made available to the biofilm by diffusion from the water.

- The waste water is applied with a rotary arm that causes it to trickle over the media intermittently.
- The end product of this breakdown by the aerobic bacteria biofilm is CO_2 . CO_2 diffuses out of the biofilm into the flowing liquid.

Treated waste water is collected through an underwater drainage system.

- 10
- Isolate mRNA from a sample.
 - Translate mRNA into cDNA (single stranded).
 - Label the cDNA with fluorescent labels.
 - Hybridize the cDNA in question with known DNA on the probes of the microarray.
 - Rinse off all other cDNA from the microarray.
 - Complementary cDNA will bind to the probe.
 - Analyse the colours present in the microarray.
- 11 The name stands for polymerase chain reaction. PCR is a procedure that takes short segments of DNA and amplifies them so that they can be identified. Numerous copies of DNA can be made by PCR (amplification).
- 12 Prostate specific antigen: this is used in a PSA test. If the PSA is elevated, this signals possible prostate cancer.
- S100 for melanoma: this is a protein biomarker that if elevated indicates high numbers of cancerous melanoma cells. Treatment of the melanoma should lower the protein biomarker.
- HER2 for breast cancer: 20–30% of breast cancer patients have higher than normal expression of this biomarker. It is important to monitor the level during treatment for some patients.
- 13 Compare:

- | |
|---|
| <ul style="list-style-type: none"> • Both are databases of gene sequences. |
| <ul style="list-style-type: none"> • Both are software used by GenBank. |

Contrast:

BLASTn	BLASTp
Database of nucleotide sequences	Database of amino acid sequences
Uses the code of DNA bases, atgc	Uses the code of amino acid names

- 14** The reasons for aligning are to see how similar sequences are in order to show:
- functional relationships, for example, genes for leptin have the same function in a mouse or a human
 - structural relationships, for example, if a scientist has isolated a protein but does not know what its function is, it can be aligned in a database and the function may be learned
 - evolutionary relationships, to find common ancestors and show phylogenic relationships.

- 15** The mouse is genetically and physiologically similar to humans. Its genome can be easily manipulated and analysed. It is a mammal, and diseases affecting humans such as cancer and diabetes also affect mice. Even if the mouse does not normally have the disease, it can be induced by manipulating the genome of the mouse. Adding to the appeal is their low cost and the ability of mice to multiply quickly. Many inbred strains and genetically engineered mutants are available for researchers. Important advances in genetic technology have given us tools to knock out mice genes, which means replacing normal genes with alternate versions. For example, the mouse with the knockout leptin gene is obese. Mice with the Cft gene can be used to study the disease of cystic fibrosis.

- (b) (i) sunlight reduces counts of faecal coliform bacteria significantly; faecal coliform bacteria fall below 1 count per 100 ml on day 2; no reduction during dark period; significant drop on day 1/bacteria count drops from 10^5 per 100 ml to less than 10^2 per 100 ml on day 1 (2 max)
- (ii) sunlight causes small reduction of coliphage viruses; coliphage virus counts never fall below 10^2 counts per 100 ml; no reduction during dark period (2 max)
- (c) coliphage viruses because they are less affected by the sun/numbers do not decrease much in 2 days (1)
- (Total 6 marks)

- 2** (a) $(12 \text{ l} \times 3 \text{ mg dm}^{-3}) = 36 \text{ mg}$ (units required) (1)
- (b) inverse relationship; approximately the same rate for decrease in terephthalate concentration and increase in methane production; linear degradation of terephthalate and methane production; at day 12 methane production starts to level out/plateaux/ terephthalate concentration is at zero (2 max)
- (c) anaerobic methanogenic bacteria/ chemoheterotroph (1)
- (d) breakdown rate is (approximately) constant; terephthalate concentration decrease and methane concentration increase are linked; concentration of 3 mg l^{-1} is non-lethal for these bacteria; breakdown is very efficient/ is 100%; breakdown is slow (as it takes 12 days) (2 max)
- (Total 6 marks)

Practice questions

- 1** (a) 28 hours after untreated sewage added
Allow answers in range 27–29 hours. (1)

- 3** (a) gene therapy involves the replacement of defective genes; viral vector (genetically) modified for (safe) use; insertion of desired gene/allele into viral genome/retrovirus; an example is the use in SCID/lack of enzyme ADA in SCID; Accept other example e.g.

cystic fibrosis; removal of somatic cells; introduction and insertion of the desired gene into the target cell; the cells are replaced in the patient so that the desired gene can be expressed (3 max)

- (b) at present gene therapy treatment effects may be short lived/process may need to be repeated/fails; reintroduction of cells/ introduction of viral vector to the patient risks immune response; viral vectors may inadvertently infect the patient; insertion of DNA may lead to tumours; risk of death (2 max)
(Total 5 marks)

Challenge yourself

1

Type of metabolism	Energy source	Carbon source	Example
Photoautotroph	Sun	Carbon dioxide	Algae
Photoheterotroph	Sun	Organic compounds	Purple bacteria
Chemoautotroph	Inorganic compounds	Carbon dioxide	Sulfur bacteria
Chemoheterotroph	Organic compounds	Organic compounds	Fungi

- 2 Both 30 and 40 s of agitation produce less citric acid than 11 s of agitation; 11 s produces the highest level of citric acid production and 40 s the lowest. In all cases of agitation the production of citric acid increases. At no time is there a decrease in production of citric acid.
- 3 High agitation seems to increase the production of citric acid.
- 4 Credit would be given to any hypothesis that is logical.
- Irritation by agitation of the mould causes it to produce more citric acid.

- Agitation produces more oxygen mixing, which increases citric acid production.
- High agitation breaks the mould into pieces, which then causes more citric acid production to be produced as it regrows.

- 5 Adoption rates of both cotton and soybean have increased over the 10-year period. Soybean has shown the largest increase. Soybean has increased from 2% to 85% ($\pm 3\%$), while cotton has increased from 0% to 60% over the 10-year period.
- 6 Soy products like tofu, soy milk, etc., are more in demand (or any other logical reason).
- 7 Both the number of hectares with no tillage and the number of hectares with reduced tillage increased from 1996 to 2001. The number of hectares with conventional tillage decreased over the same 10-year period.
- 8 Increase in areas with no tillage from 1996 to 2001 may be because of GR soybeans. GR soybeans required less tillage because weeds are killed by the herbicide glyphosate. There is then no need to till to get rid of the weeds.
- 9 Less tilling results in less damage to soil, rivers, and air.
- 10 The resistance of weeds to glyphosate has increased from zero weeds that were resistant in 1996 to six species that are resistant to glyphosate as of 2005.
- 11 Possible causes:
- Increased use of glyphosate-resistant soybean and corn crop means increased spraying of fields. Those weeds with a genetic resistance will survive and reproduce.
 - Weeds with natural resistance will begin to occupy fields.
 - Weeds spread rapidly and reproduce quickly so resistant weeds will increase in numbers.
 - The spraying is actually 'selecting' for the 'strongest' weeds.

- 12 During years of 1996 to 2003, numbers of resistant species of weeds remained low. During those seven years no more than two species of weeds displayed resistance to glyphosate in the USA. In contrast, between 2003 and 2005 the increase increased from two up to six species of weed that had become resistant to glyphosate.
- 13 Possible answers:
- Spray the fields with a different herbicide that corn and soybeans are resistant to but not the weeds.
 - Till the fields to destroys the resistant weeds for several years (although that is a farming practice we are trying to avoid).
 - Plant different crops (crop rotation).
 - Plant cover crops to increase the heath of the soil and prevent week growth.
- 14 (b) has a stop code in the middle so a complete protein cannot be made.
- 15 Both increase oil degradation compared with the control. CBMI plus glycerol resulted in 85% oil degradation and CMBI alone resulted in only 70% oil degradation. With glycerol there was better oil degradation.
- 16 Glycerol and inorganic salts.
- 17 Nutrients and minerals.
- 18 They emulsified the large oil drops into small droplets and provided more surface area upon which the bacteria could act.
- 19 *Pseudomonas* increases its ability to degrade oil with the addition of inorganic salts. Fertilizers are full of nitrates and phosphates, which are inorganic salts.
- 20 100%
- 21 $56\% \pm 3$
- 22 No, because 100% survive in the tolerance range. It does not seem to be a limiting factor.
- 23 Only two of the following (if more than two, only count the first two answers): dissolved oxygen, pH, salinity, predators, pollutants, and any other logical answer.
- 24 Three, because there are three red areas on the microarray.
- 25 B1, C2, A4.
- 26 Four, because there are four green areas in the microarray.
- 27 A2, B3, C4, D3.
- 28 Both genes are expressed.
- 29 A1, D1, D2, C3, B2.
- 30 Neither of the genes are expressed.
- 31 C1, B2, A3, D4.
- 32 The red ones, as these genes are not expressed in normal cells, only in cancer cells.
- 33 The green ones, as they are expressed in normal cells and not in cancer cells.
- 34 mRNA: AAU AGG UAC ACG
cDNA: TTA TCC ATG TGC
Probe: AAT ACC TAC ACG This is the DNA that is on the microarray
- 35 Patients A and B.
- 36 The optical densities of both are above the cut-off number for a positive result.
- 37 The numbers measure the amount of colour change caused by the IgG antibody, with the enzyme attached acting on the substrate and causing a strong colour change.
- 38 Patient C needs to be retested becasue the results are indeterminate. Patients A and B need to be retested with a different test to confirm the diagnosis.
- 39 The positive control contains antibodies for Lyme disease, so tells us that the procedure is working well.
- 40 The negative control contains no antibodies, so is a check for false positives.

- 41
- Remove ADA-deficient T cells from the patient.
 - Clone the normal ADA gene
 - Genetically disable a retrovirus.
 - Add the cloned ADA gene to the retrovirus.
 - Culture the deficient T cells from the patient with the retrovirus containing the normal ADA gene
 - The deficient T cells in the culture will be infected by the retrovirus and be given the normal ADA gene
 - Reinfuse the T cells that have back into the SCID patient
 - The genetically altered T cells will produce the needed ADA.

Answers

Chapter 14

Answers are not provided for questions that require individual research or practice.

Exercises

- 1 A good method to determine whether an organism is a keystone species is to perform a removal experiment. Ecologist Robert Paine first attempted this method. He was studying an intertidal area of western North America. When Paine removed the sea star, *Pisaster ochraceus*, manually from the intertidal area, a mussel, *Mytilus californianus*, was able to take over the rocky area and exclude algae and other invertebrates from that zone. *M. californianus* simply took over the space with no sea star to keep it in check. It was evident that it was the sea star that limited the number of mussels that could reproduce and attach to the rocks. Paine collected data to show that when sea stars are present, 15–20 different species of invertebrates and algae are present. Without the sea star, the diversity rapidly declines to five species. This supported the hypothesis that the sea star was the keystone species. When it was present, it had control over the diversity of the community. When it was absent, the diversity was lost.
- 2 In order to study the distribution of marram grass in the coastal dune ecosystem and show how it is affected by the abiotic factor of soil pH do the following.
 - At right angles to the sea, lay a tape in a line all the way up the dunes.
 - Every 10 or 20 m along the tape, mark out a quadrat (a square of a certain size).
 - Identify and count the tufts of marram grass in the quadrat.
 - Take several samples of the soil in each quadrat and use a soil test kit to determine the pH of the soil.
 - Record all the data in a table
 - Construct a graph to show the pattern of distribution of marram grass from the youngest dune to the oldest dune and see if it correlates with changes in the soil pH.
- 3 Zooxanthellae are single-celled algae that live in the tissue of reef-building coral. The coral provides the compounds and the environment for photosynthesis for zooxanthellae. In turn, the algae provide food for the coral. It gives the coral a boost of nutrients so that it can secrete the skeleton of calcium carbonate that it needs to build the reef. This is a highly efficient exchange of nutrients in a nutrient-poor environment.
- 4 One way of describing energy flows and nutrient recycling is to look at Gersmehl diagrams of different biomes. These diagrams are a common method of demonstrating the cycling of nutrients within the main 'stores' of an ecosystem. Arrows of varying thickness represent nutrient transfer. Circles of varying size represent the size of the stores.
- 5 Closed systems exchange energy but not matter. No natural system on Earth is considered to be closed, but the entire planet can be considered 'almost' closed. Large amounts of light energy enter the Earth and eventually return to space as heat, but matter is not exchanged.
- 6 Compare: Both energy pyramids have a similar shape. Both energy pyramids typically show greater efficiency levels as you move up the pyramid.

Contrast: The numbers of trophic levels are different.
- 7 When two species have a similar need for the same resources, such as food, one will be excluded. In Australia, when the cane toads attain high population densities, they consume a large number of invertebrates. Three endemic species have declined due to the competitive exclusion of the cane toad. The three examples follow.

- Cane toads (CT) are thought to consume 200 beetles, ants, and termites per night. A decline in some small reptile species has coincided with the increase in the CT population. Competition for food is inferred as the reason for the population decline.
 - A burrowing frog, *Limnodynastes omatus*, shows no survival of tadpoles in ponds where CT tadpoles are present. Direct predation on tadpoles is not significant, so competition for food is inferred.
 - Small skinks (blue-tongued lizards) began to disappear once the cane toad arrived. Both are insectivores and it is hypothesized that the skinks were outcompeted by the cane toad for insects due to the voracious appetite of the toad.
- 8**
- Accumulation of more and more plastic debris because of the failure of plastics to break down.
 - Ingestion of microplastic pieces by marine organisms, causing damage to their digestive systems.
 - Absorption of the components of the plastic or adsorbed chemicals on the plastics by the ingesting organism.
 - Accumulation of those chemicals in the body of the ingesting organism.
- 9**
- DDT is a persistent organic pollutant (POP). In 1972 the USA banned DDT and these pay-offs have followed. Peregrine falcons have come off the endangered species list. Bald eagles will soon follow. DDT levels in human blood samples have declined sharply. DDT has disappeared from the breast milk of nursing mothers.

But there is another side to the story: the difficulties of malaria control for some nations are significant. Without indoor resident spraying hundreds of mosquitoes can enter a house compared with no mosquitos entering a house that has been sprayed. Often those mosquitoes are carrying the malarial parasite. Many health officials would like to use DDT to ease

the suffering of their populations, but donor governments refuse to allow DDT spraying.

- 10**
- A breeding programme for Mexican gray wolves began in 1981. At the beginning of the programme, there were only five wolves known in the wild.
- In 1997, due to the availability of wolves bred in captivity, the USA reintroduced the gray wolf into areas of Arizona and New Mexico. In 2010 there were 59 wolves living in these areas.
- 11**
- Edge effect describes what occurs at habitat boundaries where two bordering communities influence each other. Factors that affect the edge can be:
- abiotic, such as more or less sunlight or moisture at the edge of a forest
 - biotic, such as the presence of certain predators at the edge.

Some species thrive only at the edges because they depend on unique resources that are deficient in the interior environment. Other species thrive only in the interior. Thus, high habitat diversity, which includes both the interior and the edge, promotes species richness in an ecosystem.

- 12**
- Latitude gradient explains the effect of climate on species diversity. The further one travels away from the equator the more the number of species declines. For example, the growing season is five times longer at the equator than that in a tundra community.

Elevation gradient explains that as, one travels to higher altitudes, species richness increases up to a point. The point is about half way up the elevation and is called the mid-point bulge. At the mid-point bulge the diversity is the greatest. After the mid-point bulge the species diversity declines.

The area effect explains that, the larger the geographic area, the more species it can support. A larger area offers a greater diversity of habitats than a smaller area. The area affect

concept began with a study of islands: the larger the islands, the more diverse the species on the island. This concept of 'islands' has been extended to mean any area that is so isolated that it can be considered an island.

- 13** Density-independent factors: factors that affect all individuals of a population equally.

Density-dependent factors: factors affect large populations and small populations differently.

Biotic factors: other organisms may immigrate or are brought to a new area and affect the sigmoid growth curve of a population by causing a decrease in natality.

Abiotic factors: environmental factors such as extreme cold, wildfires or hurricanes, can affect the sigmoid growth curve of a population by causing increase in mortality.

- 14** Limiting factors can be top down or bottom up. The limiting factors that you have seen define the carrying capacity of a population can exert top-down control, such predators, and bottom-up, such as nutrients.

- 15** Gathering data from fishermen: data should be gathered from several sources to cross check the fishermen. Cross-check data from log books against sales slips. This method can enable the statistical data to at least show the accuracy of data that is reported, for example 100 mackerel ± 10 were caught on 12 December 2014 by the fishing vessel *Lady of the Sea*. Requiring computers on large fishing vessels with automatic data-logging software would improve counting accuracy and communication of total fish counts to a central location.

- 16** Denitrifying bacteria change nitrates back to free nitrogen. This nitrogen is then released back to the atmosphere and is not available for plants to use for protein synthesis.

- 17**
- Both are necessary for plant growth.
 - Both are necessary for the production of DNA and ATP.
 - Both are mineral nutrients in the soil.

- Both are found in fertilizers.
- Nitrogen is more easily available than phosphorous.
- The nitrogen cycle is faster: the phosphorus cycle is very slow.
- Nitrogen has a substantial atmospheric pool. The pool of phosphorus is in marine sedimentary rocks.

- 18**
- Mutualistic nitrogen fixation: some bacteria form a symbiotic relationship with a host plant and fix nitrogen for the plant.
 - Free-living nitrogen fixation: some bacteria live freely in the soil and fix nitrogen.
 - Industrial nitrogen fixation: burning fossil fuels to produce fertilizer is an important source of fixed nitrogen.

Practice questions

- 1**
- (a) parasitism increases with increased deforestation; some species are more greatly affected than others (1 max)
- (b) same level of parasitism at 28% deforestation; both are increasingly parasitized with deforestation; at low levels of deforestation worm-eating warbler is less parasitized; at high levels of deforestation worm-eating warbler is more parasitized (2 max)

Accept converse.

- (c) 64–67% (1)
- (d) cowbird niche occupies larger area so cowbird population increases and parasitism increases; cowbird prefers host nests in open areas because food source is in open area; birds cannot build nests far enough from cowbird habitat when wood patches are small; host species populations reduced so parasitism becomes more intense; easier for cowbirds to find host nests in open

woodland/host species concentrated into smaller area (2 max)

(Total 6 marks)

- 2 (a) index/ D is a measure of species richness; a high value of D suggests a stable/ancient site; a low value of D could suggest pollution/recent colonization/agricultural management/environmental stress; the index is normally used in studies of vegetation diversity (but can also be applied to comparisons of animal/all species diversity); involves collecting data on variety of species; and relative numbers (3 max)

- (b) indicator species are organisms that need particular environmental conditions; diversity/abundance/groups of species/relative numbers of indicator species can be used to construct a biotic index; biotic indices are used to monitor environmental change/status; only organisms sensitive to specific environmental condition are included in the biotic index; example of indicator species and condition to which it is sensitive *e.g. stonefly lives in highly oxygenated water.*

tubifex lives in poorly oxygenated water.

crustose lichens, tolerant to air pollution.

fruticose lichens, intolerant to air pollution.

other example.

any change in the environment will be seen as a change in numbers of these species/groups; indicator species/biotic indices can be used to indicate pollution; pollution can be seen by overall decrease in diversity/increased in numbers of tolerant species; examples of biotic index (*e.g. lichens communities and air pollution, fresh water invertebrates and organic water pollution*)

(6 max)

(Total 9 marks)

- 3 (a) Award (1 mark) for each of the following processes correctly placed and labelled. nitrogen fixation (free-living, symbiotic, lightning and industrial)/ N_2 converted to NH_3 ;

denitrification; nitrification/ NH_3 converted to NO_2^-/NO_3^- ; feeding; excretion; root absorption; putrefaction (ammonification) (3 max)

Do not accept decomposition.

- (b) methane; wood; ethanol (2 max)

*If the candidate gives more than two answers for this question mark **only** the first two given. Do not accept coal or petroleum.*

- 4 (a) $19\,580\text{ kJm}^{-2}\text{yr}^{-1}$ (units required) (1)

- (b) (i) autotrophs lose 55% of their gross products to heat compared with the heterotrophs which lose 96.3% (96) of their food energy/41% more of heterotrophs (1)

Numerical comparison required

- (ii) animals use a lot of energy to move/maintenance of body temperature/other valid reasons (1)

- (c) decomposers are responsible for the recycling of (inorganic) nutrients/breakdown of organic molecules to inorganic compounds (1)

- (d) autotrophs need nutrients (from the soil); decomposers release these nutrients; fewer decomposers will lead to slower/less recycling of nutrients; limits growth of autotrophs; limits (net/gross) productivity of autotrophs (2 max)

(Total 6 marks)

- 5 (a) primary consumer (1)

- (b) June to August 1994 (1 month); May to June 1993 (1 month) (1 max)

- (c) there is a rise in the population starting every (Antarctic) summer; every year numbers remain low from March until November/ from autumn until the beginning of summer; no data available for spring 1994; increase in numbers coincides with increase in light; decrease in numbers during fall/autumn (2 max)

- (d) (i) lowest sea water temperature is associated with highest numbers of larvae; larvae numbers increase when temperature drops below -1.5°C ; no larvae at temperatures above -1.5°C ; bigger increase in numbers during July/September 1993 than in July/September 1994 although temperatures the same (2 max)
- (ii) global warming causes rise in sea water temperature; lower numbers of larvae; because larvae only present at sea water temperature below (2)

(Total 8 marks)

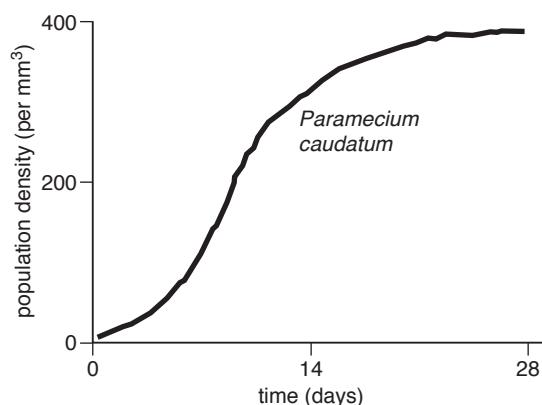
Challenge yourself

- Sea otter.
- As the sea otter population declines because it is being eaten by orcas, the sea urchin population increases. Seas urchins are not eaten because of the lack of sea otters. The kelp bed, which was once abundant, is now in a serious decline because it is being eaten by the sea urchins.
- Any logical answer is acceptable:
 - pollution of the North Pacific is killing seals and sea lions
 - overfishing has eliminated the food supply of seals and sea lions
 - oil spills have killed seals and sea lions.
- Predation: The blue heron is a predator on a frog in the pond of the sand dunes.
 - Parasitism: Leeches are parasites that live in ponds. Their hosts are humans and other mammals. The leech punctures the skin of the host and secretes an enzyme into the wound to prevent clotting and begins to ingest the blood.

- Mutualism: Lichen is a mutualistic relationship between algae and fungi. Algae photosynthesize and make carbohydrates, (food). The fungi absorb the minerals ions needed by the algae.
- Herbivory: Rabbits eat the marram grass in the sand dune ecosystem.
- Competition: In the coastal dunes of the UK, the natterjack toad, *Epidalea calamita*, is facing tough competition from the common toad, *Bufo bufo*.

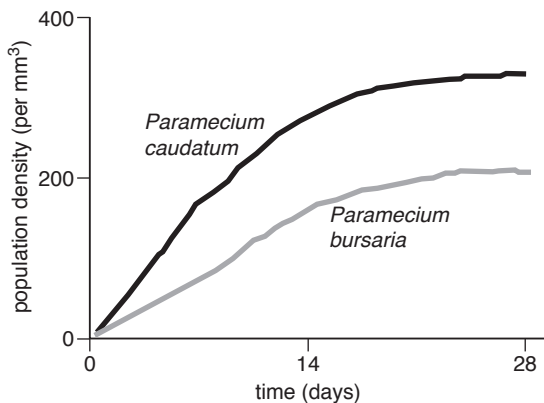
5

Sample per mm^3	Day 7	Day 14	Day 21	Day 28
1	143	200	300	390
2	155	205	315	360
3	165	185	295	375
4	135	235	350	365
5	143	195	295	410
6	145	265	320	370
7	165	265	340	380
8	175	195	370	390
9	105	215	325	390
10	169	290	340	320
Mean	150	225	325	375



6 Fundamental niche.

7



8 This is a picture of the realized niche of *P. caudatum*. The realized niche shows a lower population density than in the first graph you drew, because *P. caudatum* is competing for resources with *P. bursaria*. *Paramecium caudatum* cannot reach the potential of its fundamental niche because of the fewer resources.

9 13.3%

10 8.7%

11 Compare: the thickness increases with age in all three areas.

Contrast: the slope had the most increase in thickness after 28 years. Both the dunes and the plains were much less thick.

12 The accumulation rate of N was much higher on the plains and the slope than on the dunes.

13 All three areas had increases in biomass.

14 Both increased.

15 The plains. Any logical answer would be accepted:

- the wind causes plants to grow that have less aerial biomass and more roots
- the wind causes dehydration so that the roots must be deep to get water from the sand
- wave action during storms washes away plants that do not have deep roots.

16 10–30°C.

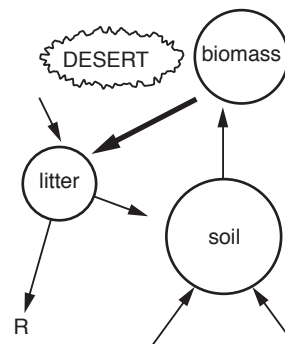
17 100 cm yr⁻¹

18 Grasslands is 6°C; tropical forest is 25°C.

19 Compare: Temperate deciduous and temperate rainforests have a very similar average temperature of about 15°C.

Contrast: Precipitation is only an average of 150 cm annually for the temperate deciduous but is 250 cm annually for the temperate rainforest.

20



Risk	Benefit
Use of copper sulfate and chlorine • Killed all living organisms • Could spread beyond the marina • Potential damage to the pearl industry • Potential damage to the prawn industry	• Killed all the mussels • Saved the pearl industry • Saved the prawn industry • Prevented the spread of mussels to other areas of Australia
Biological control <i>Pseudacteon</i> flies could become a pest because they have no predators Money will be spent but the flies will not control the fire ants	The flies could save millions of dollars spent on insecticides Use of insecticide could be eliminated, thus protecting the environment
SIR Some insecticide must be used to keep Japan completely free of the oriental fruit fly Strict inspection is necessary but expensive	SIR is not introducing another species into the ecosystem. Japan is free of the oriental fruit fly The programme is not costly and is environmentally friendly

- 22** Crayfish had uniformly the lowest concentration of HgT, and smallmouth bass had the highest concentration of HgT.
- 23** Compare: CPP had HgT accumulation in invertebrates and fish, BFR also had HgT accumulation in invertebrates and fish.

Contrast: CPP had the highest HgT concentration in crayfish, smallmouth bass and hog suckers of any site.

BGR had the lowest HgT concentration in crayfish, smallmouth bass and hog suckers of any site.
- 24** Smallmouth bass are the highest organisms in the food chain. At each level organisms are bioaccumulating mercury and the top predator eats organisms that have already concentrated mercury in their tissues.
- 25** Site alone accounts for the large variation in hog sucker HgT. Both smallmouth bass and hog suckers had higher HgT at lengths of 250–300 mm whether collected from sites EPR or CR, versus those collected from BGR. So it was not the length but the site that made the difference.
- 26** BGR. It is the site where the least amount of HgT is found accumulating in the fish.
- 27** The fewest bird species live on the smallest island, and the most live on the largest island.
- 28** Island area was the greatest predictor of species richness.
- 29** The number of species increases with the area of a lake.
- 30** There were more western meadowlarks detected in the areas with greater distance from woody vegetation.
- 31** Habitat suitability was negatively affected by distance to woody vegetation or suitability of habitat seems to be grassland not a wooded area.
- 32** Any logical answer, for example what effects on grassland bird populations are caused by the 'edges' created by roads or hiking trails.
- 33** Crustose corallines decreased with elevated nutrients, which was harmful to the coral.

Fronlose macroalgae increased dramatically from 21% to approximately 64% cover. This was also harmful to the coral.

Algal turfs decreased. This was beneficial to the coral but overall the corals were harmed by elevated nutrients and low herbivory.

- 34** Yes, the prediction was correct. With elevated nutrients, the crustose corallines achieved only 1.7% of cover and the algal turfs 14.5% of cover, while the macroalgae covered 63.7% of the space
- 35** At site D, with elevated nutrients and high herbivory, the crustose corallines achieved almost 72% cover. This was beneficial to the reef because this alga helps build the reef. High herbivory along with elevated nutrients allowed the crustose corallines to outcompete the other two types of algae.
- 36** Eutrophication-induced macroalgal blooms are caused by elevated nutrients. When this is combined with low herbivory, the macroalgae dominate, as is evidenced by the 63.7% cover that was measured at site B. The macroalgae outcompetes the reef-building crustose corallines algae.
- 37** The large and mature fish population is reduced. Evidence: the biomass of the fish population declines after age 11.
- 38** Grouper with higher and higher reproductive status from age 11–32 are lost. A reduction of older, mature, fecund sizes and ages of grouper leads to reduced reproductive potential.
- 39** Population size is highly biased towards small fish.
- 40** Increase the size limit to 48 inches so that fish caught would be from a more mature stock, giving fish a longer reproductive life.
- 41** Education explaining that eventually there will be no more grouper to catch if this is not implemented.

Answers

Chapter 15

Answers are not provided for questions that require individual research or practice.

Exercises

- 1 Essential minerals, essential vitamins, essential fatty acids, and essential amino acids.
- 2 Essential nutrients cannot be synthesized by the body from other molecules. Non-essential nutrients can be synthesized from other molecules if needed.
- 3 The vast majority of animals (including rats and mice) are able to produce vitamin C from other molecules. Thus, for those animals, vitamin C is not an essential vitamin. Humans, a few other primates, and guinea pigs are the only known mammals where vitamin C is essential.
- 4 Rickets affects bone plate formation in children; specifically, bone mineralization does not occur properly at the bone plate areas. Only children have bone plates, which are involved in bone lengthening and overall growth. However, adults who have insufficient vitamin D intake can acquire a similar disease known as osteomalacia.
- 5 HCl: denatures proteins to allow easier enzymatic digestion and kills many possible pathogens (e.g. bacteria) in foods. Pepsinogen: activates pepsin, one of the protein-digesting enzymes. Mucus: protects the inner stomach wall from acid damage.
- 6 Stomach or gastric ulcers are not caused by stress, but instead by an infection of a bacterium known as *Helicobacter pylori*. This bacterium resides under the mucus layer of the stomach and produces ammonia to help neutralize stomach acid in its immediate area. Someone with the symptoms of gastritis or ulcers may respond well to antibiotics.
- 7 Microvilli to increase greatly the absorption surface area; many mitochondria to create ATP for active transport of some nutrients; tight junctions to make sure nutrients cannot 'leak' between cells; basal labyrinth to increase the surface area of the membrane for nutrients to exit the epithelial cells.
- 8 Exocrine glands produce and secrete a substance that is useful in a specific location in the body. Therefore, after secretion, the substance is taken to a specific location via a duct(s).
- 9 There are two major blood vessels that take blood into the liver. Both of these blood vessels empty their blood into the same sinusoids. One of these vessels is the hepatic artery, a branch of the aorta, which carries oxygenated blood. The other vessel is the hepatic portal vein, which receives varying amounts of nutrients from the villi capillaries and then carries these nutrients into the liver. There is only one major vessel that takes blood out of the liver, and that is the hepatic vein.
- 10 The vast majority of iron is recycled. Kupffer cells ingest 'old' red blood cells or haemoglobin from the blood. The iron is removed, and some is stored in the liver and some is sent to the bone marrow where new cells are forming. Only a small amount is needed for blood loss, growth of an individual, or to make up for the little lost in the recycling process.
- 11 Both of these situations would lead to blood glucose becoming relatively low in the bloodstream. Under this situation, the pancreas would secrete the hormone glucagon. Glucagon would travel in the bloodstream to the hepatocytes in the liver, and stimulate the conversion of stored glycogen (a polysaccharide) into glucose. This glucose would then enter the blood via the sinusoids and be available for cell respiration.
- 12 One of the primary functions of the liver is to remove toxins from the blood. Alcohol (ethanol)

is a toxin to body tissues. During the removal process, hepatocytes are exposed to ethanol for a longer period of time than most body tissues, and are damaged, sometimes leading to cirrhosis of the liver.

- 13** Artificial heart valves open and close according to the same forces as the original biological valves. Valves open or close based on the difference in blood pressure on either side of the valve.
- 14** The overall pattern will be the same except that the frequency of cardiac cycles will be increased. The x-axis of an ECG is time and there will be a greater number of cardiac cycles per unit of time.
- 15** The SA node results in atrial systole, ensuring blood has been moved to the ventricles. When the AV node sends its signal, the resulting increase in pressure because of the beginning of ventricular systole ensures that the atrioventricular valves close, and thus a very high pressure can build up in the ventricles, ultimately opening the semilunar valves. Blood is then moved into the aorta and pulmonary artery. The time delay allows the separation of events between the atria and ventricles.
- 16** Cardiac muscle cells are joined together end to end by intercalated discs containing many protein channels called gap junctions. These gap junctions allow easy movement of the electrical signal from one cell to the next.
- 17** Steroid hormones enter a target cell directly through the plasma membrane. Within the cytoplasm they bind to a receptor to form a receptor–hormone complex. This complex then enters the nucleus and either promotes or inhibits the transcription of a particular gene.

Peptide hormones do not enter the cell. Instead the hormone binds to a receptor protein on the outside of the plasma membrane and the receptor protein then begins a series of events leading to secondary messengers either activating an enzyme or regulating transcription.

- 18** Exocrine glands produce a secretion that is useful in a specific location in the body and is taken to that location by a duct. Typically the location is not far from the gland.

Endocrine glands produce hormones that are useful to cells that are often far from the gland. Their mode of transportation is the bloodstream.

- 19** The posterior pituitary does not produce any hormones, but it secretes two, oxytocin and ADH. Both of these hormones are produced by the hypothalamus and then travel through neurosecretory cell axons to the posterior pituitary to be stored and later secreted as needed.
- 20** Oestrogen is a hormone that inhibits the secretion of breast milk. Oestrogen levels remain high in the mother's blood until after birth.
- 21** Both adult myoglobin and foetal haemoglobin need to be able to pick up oxygen that is dissociating from adult haemoglobin, as adult haemoglobin is the source of oxygen for both. Adult haemoglobin would not give up oxygen to the foetal haemoglobin and adult myoglobin molecules if it had a greater affinity for oxygen than them. The course of molecular evolution has ensured that these molecules interact in the way that they do.
- 22** Because the Bohr shift results in haemoglobin dissociating from oxygen when more carbon dioxide is bound to haemoglobin, this ensures that the oxygen release by haemoglobin is most efficient when body tissues (muscles specifically) are most active, i.e. during exercise. More oxygen is then available to muscle tissue at a time when it is needed most.
- 23** The use of muscles results in a higher rate of cell respiration and thus a higher rate of carbon dioxide production. Carbon dioxide enters the blood stream and then most enters a red blood cell. An enzyme called carbonic anhydrase catalyses the conversion of carbon dioxide into carbonic acid. Carbonic acid then spontaneously dissociates into hydrogen carbonate ions and

hydrogen ions. It is these hydrogen ions that are lower the pH.

- 24 Because the blood never was nor ever will be acidic. The homeostatic range of blood plasma is 7.35 to 7.45, a range that is entirely within the alkaline (basic) pH values.
- 25 The rate of ventilation is one of many factors controlled by our autonomic nervous system. In this case, carbon dioxide and pH sensors within the aorta and the medulla oblongata are monitoring for increased carbon dioxide levels and the corresponding lowering of pH, and impulses will be sent to the appropriate muscles (from the medulla oblongata) when needed.

Practice questions

- 1 (a) a substance required by the body to provide energy, maintain health or to provide material for growth and repair; one of the components in a balanced diet (1 max)
- (b) rickets is the result of poor bone growth/ poor calcification of bones; vitamin D/ calciferol deficiency in diets can lead to rickets; calcium deficiency in diets can lead to rickets; vitamin D can be obtained from (fish) liver; vitamin D can also be synthesized by the action of UV light on pro-vitamins in the skin; pro-vitamins of vitamin D can be obtained from green vegetables; rickets may also be caused by a hereditary disease; rickets can be caused by poor calcium absorption (3 max)
- (Total 4 marks)
- 2 oxygen dissociation curves describe saturation of hemoglobin by oxygen; over a narrow range of partial pressure of oxygen; which typifies oxygen pressures surrounding cells under normal metabolism; increased metabolism results in greater release of CO₂ into blood; CO₂ lowers pH of blood; increased acidity shifts oxygen dissociation curve to right; results

in release of oxygen from hemoglobin; at the same partial pressure of oxygen; ensuring that respiring tissues have enough oxygen; when their need for oxygen is greatest; also, saturation of hemoglobin occurs at higher partial pressures of oxygen; so that it can release oxygen at higher partial pressures

(Total 6 marks)

- 3 (a) (i) parsley (1)
- (ii) egg (1)

If the answers to (a) (i) and (ii) are correct, but inverted, i.e. (i) egg and (ii) parsley, award [0], but apply Error Carried Forward (ECF) to marking points (b) and (c). Write ECF beside the answer and use the alternative marking points given below.

- (b) plant products more effective overall/animal products least effective; the three/four/five most effective foods are all plant products/ ratios given of three plants; but soy beans is an exception/similar to egg; potato and skimmed milk are similar in effectiveness

With ECF:

plant products least effective overall/animal products more effective; the three/four/five least effective foods are all plant products/ ratios given of 3 plants; but soy bean is an exception/similar to egg; potato and skimmed milk are similar in effectiveness (3 max)

- (c) give supplements of parsley/garlic/onion to a group of people; use women after the menopause/with osteoporosis; use women with ovaries removed; have another control group of similar people who are not given the supplement; measure changes in bone density during the trial period/measure calcium loss

With ECF:

give supplements of egg/meat/soy-bean to a group of people; use women after the menopause/with osteoporosis; use women

with ovaries removed; have another control group of similar people who are not given the supplement; measure changes in bone density during the trial period/measure calcium loss (3 max)

(Total 8 marks)

4 (a) 93% $\pm$ 1% (1)

(b) (i) increases by 0.63 mmol l⁻¹ of blood/
rises from 15.59 to 16.22 mmol l⁻¹ (1)

(ii) dissolved CO₂ (1)

(c) CO₂ makes the blood more acidic and the pH drops; pH of venous blood at rest has decreased compared to arterial blood; because the blood is carrying waste CO₂ (from cellular respiration) back to lungs for removal; pH of venous blood after exercise has decreased compared to arterial blood; and dropped even further than venous blood at rest; because the blood is carrying more waste CO₂ than normal due to exercise (3 max)

(Total 6 marks)

5 erythrocytes rupture when they reach the end of their life span/after 120 days; absorbed by phagocytosis/Kupffer cells in liver from blood; hemoglobin split into globin and haem groups; iron removed from haem leaving bile pigment/bilirubin; bilirubin released into alimentary canal; digestion of globin to produce amino acids

(Total 4 marks)

Challenge yourself

1 The electron micrograph clearly shows the increased surface area because of the numerous

microvilli on the side of the epithelial cell in contact with the lumen of the intestine. There are numerous mitochondria within the cell for production of ATP for active transport of some nutrients through the membrane. A tight junction is also shown preventing 'leakage' of nutrients between the two cells.

2

Hormone	Produced by	Secreted from	Target tissue
(a) ADH	Hypothalamus	Posterior pituitary	Collecting ducts of the kidneys
(b) FSH	Anterior pituitary	Anterior pituitary	Ovaries and testes
(c) Progesterone	Corpus luteum and placenta	Corpus luteum and placenta	Muscles, particularly the uterine muscle
(d) Oxytocin	Hypothalamus	Posterior pituitary	Uterus muscle and various other cells

3 (a) Every TEM is of a sectioned cell. There were three red blood cells in this area of a small blood vessel and the section created these three shapes.

(b) Three. First, the alveolar cell plasma membrane. Second, the capillary cell plasma membrane. Third, the plasma membrane of the red blood cell.

(c) Interphase. The evidence for this is the chromatin (rather than chromosomes) in the nucleus.

(d) A red blood cell within a second blood vessel cut in section.